Interviewee: Leonard Kleinrock 被采访人：伦纳德·克兰罗克
Interviewer: Bu Zhong 采访者：钟布
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Transcriber & translator: Mao Runqing 转录&翻译：毛润卿

Abstract
The interview is about Leonard Kleinrock, father of the internet, American engineer and computer scientist. He contributes greatly to computer internet and plays a vital role in the development of ARPANET and internet. His queuing theory is well known all over the world. This interview is about his life, contribution, teaching career and all the aspects people would love to know.

摘要：这是一篇关于伦纳德·克兰罗克的采访。他是公认的“互联网之父”，美国工程师和计算机科学家，为计算机网络做出了杰出贡献，在阿帕网和互联网的发展中起到了非常重要的作用。他的队列理论也为世人熟知。这篇采访问及他的生活、所做贡献、教学生涯和人们想知道的关于他的方方面面。

（1:28）
LK: I have to greatly improve the room you are looking at that now we have very few funds to… Here it is. Right here. Thirty-four twenty. Now you have to realize that as you enter this room (that) it’s a holy room and you’re going back almost fifty years, so you have to mind go back in time. This is where the Internet began. That’s the first piece of in Internet equipment. That’s the IMP (Interface message processor). This I say is the first piece of Internet ever used. It's an interface message processor. It’s now called the router or it’s called the packet. It’s a military bought machine. It doesn’t run any more. It was built by Bolt, Baranek, and Newman. I’ll give you the whole histories when we get there. It’s a beautiful machine. I suspect in the documentary what looks like inside…It’s a magnificent machine. As I say, it is so ugly it’s beautiful. It’s close to state-of-the art equipment as of that time, with all the usual components of logic, the CPU, with the memory, the modem interface, the power supply and all of that. A great machine and it ran for many years. There are only two of these left out of the many dozens that were available originally, and this is IMP No.1, the very first one. Computer history museum has IMP No. 10. All the rest were thrown away, and they tried to throw this away, and I had to fight with the university administration to keep it. In fact, when Dobb, who found this, once the project ends, the equipment was moved back to the critical investigators. I said you can’t put this away and for many years it was in my office just to keep it away from people wanting to take it away. But you know it is a great machine. It’s IMP No. 1 as I say, Interface Message Processor developed by Bolt, Baranek and Newman. And it’s a terrific machine you can download any register you want and you can change the contents, and wonderful diagnostic. It’s a very important machine. Let me ask you a question:

How many revolutions do you know (and there have been many revolutions) can you say the exact minute when it began, the exact four square feet where it began? Not too many. This one now this one this happened right this machine was right here plugged into that power supply. On Oct 21, 1969, at 10: 30 that night, the first message was sent between the first two computers, and that spotted the beginning of what we have today.

伦纳德·克兰罗克：虽然资金很少，我还是不得不把你们正在看的这间屋子进行了大的改进。就是这儿了。口令是 3420。现在当你进入这间屋子时，你们必须意识到，这是一间神圣的房间，你们将回到大约五十年前，所以你们要注意及时回到过去。这就是互联网开始的地方。那是第一件互联网设备。那是 IMP（接口信息处理器）。要我说，它是第一件互联网设备，是一个接口信息处理器。现在人们称它为路由器或是信息包。它是为军事而购买的机器，现在已经不再运行，博尔特、巴拉尼克和纽曼合力建成了它。等我们走到那里，我再告诉你们它的整个历史。它是一台非常漂亮的机器，我想知道在纪录片里，这台机器里头会是什么样子的。这是一台宏伟的机器。就像我说的，它样子丑陋，却很漂亮，技术和当时最先进的设备相当接近，拥有所有常见的逻辑电路、CPU、内存、调制解调器接口、电源等全部组成部件。这是一台伟大的机器，运行了很多年。原先能用的几十台机器中，只有两台至今还在，这就是 IMP 一号机器，建造出来的第一台。计算机历史博物馆里有 IMP 十号机器，其他所有的机器都被扔了，他们也打算把这台扔掉，我不得不和大学行政层进行斗争才把它保留下来。事实上，找到这台机器的多比说，一旦项目结束后，这台设备要归还给那些重要的研究者。我说，你不能把它收走，多年以来它就一直在我的办公室里，这只是为了让它远离那些想把它带走的人们。但你明白，它是一台伟大的机器。就像我说的，它是 IMP 一号机器，由博尔特、巴拉尼克和纽曼开发出来的接口信息处理器。用这台超棒的机器，你可以下载想要的任何寄存器，并能改变其内容，进行美妙的诊断。它是一台非常重要的机器。我想问你们一个问题：你们知道多少场革命（迄今为止有许多场革命）？你们能说出每场革命开始的准确时间和精确地点吗？恐怕说不出多少吧。这台，现在这台，就是在这儿，插入了那个电源。在 1969 年 10 月 21 号晚上 10 点 30 分，第一条信息就是在这最初的两台计算机中间发送出去的，它标志着我们现在拥有这一切的开始。

（5:01）

BZ: From here to Stanford?

LK: Stanford Research Institute, yes, 350 miles to the north and I can describe that process if you like. Before we get there, this is the UCLA newspaper. On July 15th, 1969, it is an article here saying UCLA will be the first node of this network. Even before that, on July 3rd, 1969, UCLA put out a press release. The UCLA press release. Tom Tooker was the journalist and I talk about what's gonna happen with this thing. Right here I have my prediction of the future and I'll read it to you. It says, "As of now computer networks are still in their infancy stage," says Dr. Kleinrock, "but as they grow up and become more sophisticated, we'll probably see the spread of computer utilities (We call those things web-based server these days) which，like present electric and telephone utilities (It means it will be everywhere and easy to use and as invisible as electricity is. Plug into the wall and you get electricity. You don't get out with me), will service individual homes and offices across the country from anywhere you get access.” So that was my vision two months before this arrived. This arrived here on September 2nd, 1969. The first message was sent a month and a half later. The thing I missed. This vision is fairly accurate. One of these things has not yet happened, and one thing I totally missed. That was that my ninety-nine-year old mother would be on the Internet before she passed away, at the same time my grandchildren were on in the Internet. I missed the entire social network side. The fact that this was not about computers talking to each other, or people talking to computers, but people talking to people and forming communities. I totally missed that. We first began to see that when e-mail came in 1972, three years later. But it was quite interesting to me. What was missing, what it doesn't even have now that it says it will have, is what I call invisibility.

钟布：从这儿发送到斯坦福？
伦纳德·克兰罗克：对，发送到斯坦福研究所（SRI），向北 350 英里，如果你想听，我可以向你描绘那个过程。在我们说到那之前，这儿是加州大学洛杉矶分校报。在 1969 年 7 月 15 号，它发表了一篇文章，说加州大学洛杉矶分校（UCLA）将会成为网络的第一个节点。甚至在此之前，1969 年 7 月 3 号，加州大学洛杉矶分校发表了一份新闻稿。加州大学洛杉矶分校的新闻稿。汤姆·图克是记者，采访了我，我说到有了它，世界会发生什么样的变化。就在这儿，我预测了未来，现在我来读读当时我的预测，它是这么说的：“‘目前计算机网络仍处于初级阶段’，克兰罗克博士说，‘但随着它们的发展成熟，我们很可能会看到“电脑工具”的传播（如今我们称之为网络服务器），它们就像现在的电力和电话公用事业（这意味着它无处不在，易于使用，像电力一样肉眼不可见。把插头插在墙上，你就拥有了电），将服务全国任何你拥有访问权限的个人家庭和办公室。’”这段话是我在这台机器抵达这儿两个月前所做的预测。这台机器是 1969 年 9 月 2 号抵达的。第一条信息是一个半月后发送的，我错过了。这个预测相当准确，这些事中有一件还没有发生，还有一件事我完全没有料到，那就是我 99 岁的母亲会在她去世之前用上互联网，与此同时我的孙儿孙女也在使用互联网。我漏掉了整个社交网络，这不是电脑与电脑之间的交谈，也不是人们和电脑之间的交谈，而是人和人之间的交谈并形成团体。我完完全全忽略了这一点。我们最开始是在三年之后的 1972 年电子邮件出现后才意识到这一点的，但这对我来说很有趣。我忽略的和我说会发生但现在还没有发生的，我称之为不可见。

These devices, computers, these things, they are far too complex. The interface is terrible: different keyboards, different voice interpretations, different apps, different presentations. It should be at this room knows that I’m here, that you’re here. You should be able to touch any piece of equipment, and it should become yours with your applications and privileges and profiles and preferences, and (you) should be able to talk to it, be able to gesture or touch. And hologram should come out; and speech should be interacted by speech, be able to touch things. But not yet there. It’s still too complex. It's happening with the Internet of things that’s beginning to happen. So let me tell you a few more things about this room. Here we see a plaque given by the IEEE (Institute of Electrical and Electronics Engineers). It is called an IEEE milestone. They give these things to places like the first intercontinental transmission, another great defense. They identified this site as the birthplace of the Internet in 1969, and it talks about the exact fact that we sent the first message from here to Stanford Research Institute. They gave it to us in Oct 2009. It's very special. Here's a picture of this room. By the way, this is a small piece of the original room, and again I had to fight to get this room back. It was a laboratory. It is extended away in that direction in a short distance here. This is a piece of it. Now what you can't see in this picture is the IMP because it's off camera. But you see this panel here: That's the control panel for the host computer. That was attached to this, the first computer attached. And there it is. There is the host computer. And you see this is control panel, but all the rest is fake. This is an empty box. The machine was thrown away but we managed to save the control panel. And what happened when that machine first arrived here, so we were in the cable from that machine to this machine to test if the IMP host interface was working, and this machine arrived just before the Labor Day weekend in 1969. You couldn't do anything over the holiday, so on the Tuesday following the Monday of Labor Day, September 2nd, 1969, we had the host connected.

这些设备、电脑，这些东西，它们实在太复杂了。接口很可怕：不同的键盘、不同的语音解释、不同的应用软件、不同的演示。它应当是在这间屋子里，我和你所在的这间屋子里。你应当能触摸任何设备，它应当随着你的应用程序、特权、文件和偏好变成你的，你应当能同它交谈、做手势或触碰它。应当会有全息图，演讲应当有互动，能去触摸物体。但不是现在，它仍然太过复杂。它会随着互联网的发展而发生。让我告诉你关于这间屋子更多的一些事情吧。这里有一块电气和电子工程师协会（IEEE）赠送的匾，它被称为电气和电子工程师协会的里程碑。他们把这些匾赠送到一些如第一次洲际传输之类的地方，都是有重大纪念意义的。他们认定这儿是 1969 年互联网的诞生地，这块匾上记载了我们从这儿向斯坦福研究所（SRI）发送的第一条信息的精确内容。2009 年 10 月，他们向我们赠予了这块匾，它非常特殊。这是这间屋子的照片。顺便说一句，这是原先房间的一小部分，我不得不再次斗争才拿回了整间屋子。这原来是一间实验室，后来向那个方向扩展了一些；这是其中一部分。在这张照片上你看不到这台接口信息处理器，因为它不在镜头里。但你能在这儿看到这块面板：这是主机的控制面板。它和这个连在一起，第一台电脑连接。就是它。这是主机。你看到的这个是控制面板，但其他所有的都是仿制的。这是一个空盒子。机器被扔掉了，但我们设法把控制面板保存下来了。当那台机器刚刚抵达这儿时，我们把电缆从那台机器接到这台机器，来测试这台接口信息处理器的主机接口是否能运行。这台机器刚好是在 1969 年劳动节前的周末运抵的，过节什么也干不了，所以在周一劳动节后的周二，也就是 1969 年 9 月 2 号，我们才把主机连接起来。

（10:09）

We had everybody here from Oregon, from UCLA, from GTE, from AT&T, from BBN, from Sigma, from XDS. They come down with more scientific data systems. I want to see if we can send bits back and forth, and everybody was ready to point the finger at somebody else if it didn't work. Happily it worked just fine. So we can send bits back and forth, but that was not a network yet. It's one node. And the idea of the network we will build, an experimental network, was to allow me at this site or anyone else at another site to log in through the network to a remote machine, and run the application or software at the remote machine from your parent location. So we need to get another system to do it and that happened a month later. But to back up a bit, the history in, how do we get to this and why was the network supported by the Department of Defense, so it started from here. I was a graduate student at MIT in, basically 1959. And I was looking around for an important topic to work on, and I really didn't want to get a PhD. I got my Master's Degree. I was supported at a very good research job in MIT, ready to go to work. And my thesis advisor said you have to get a PhD. I said, "No, I have scheduled at least my son has just been born, I'm ready to go to work." "So that you have to go on," he said. I'm going to go on. I have two conditions. I want to work for the absolutely best professor in MIT, and I want to do something with impact. Not some little thing that doesn't amount to anything. And so I looked around at MIT at Lincoln Laboratory, and I was surrounded by computers but they couldn't talk to each other. And I knew that sooner or later, they'll want to talk to each other. And there's no adequate networking technology for data communications. The voice telephone network was excellent for voice communications, but its technology couldn't support the kind of traffic that's generated by the computer.

这儿每个人都来自俄勒冈州、UCLA、美国通用电话电子公司、美国电话电报公司（AT&T）、BBN 科技公司、西格玛公司和 XDS 公司。他们拥有更科学的数据系统。我想看看我们是否能来回传送比特，而每个人都准备好了如果传送失败就要指责其他人。开心的是它工作得很好。所以我们可以来回传送比特，但那还不是网络；它只是一个节点。我们将建立网络，一种实验性网络，这个想法让我能在这个位置、或是其他任何人在另一个位置，通过网络登录到远程计算机，并从你的父窗口运行远程机器上的应用程序或软件。所以我们需要另一套系统来实现它，这在一个月之后完成了。但要备份比特和历史，我们怎样才能实现这一切以及为什么国防部要支持网络呢？它是从这儿开始的。当时，主要是在 1959 年，我还是麻省理工学院（MIT）的一名研究生，那时我在寻找重要课题来研究，而我真的不想去拿博士学位。我已经拿到了硕士学位，在 MIT 获得了一份非常好的研究工作，准备开始上班。我的论文导师说你必须拿到博士学位。我说："不，我计划好了，至少我儿子刚刚出生，我准备去上班了。"他说："所以你必须继续读下去。"我要继续研究，有两个条件。我想要为麻省理工学院最好的教授工作，还想做一些有影响的事。不是没什么意义的事。所以我在 MIT 的林肯实验室四下环顾，身边都是计算机，但它们没法彼此交谈。我知道迟早它们会想要交谈的。那时没有足够的数据通信网络技术，能进行语音通信的语音电话网络非常好，可它的技术无法支持起计算机生成的那种通信量。

You know, in voice we set up a connection between me and you through a network, and we started talking and while we are talking, the entire link, sequence of links is dedicated to our conversation. If I pull this, that link is being wasted. It turns out about one third at the time, the link is idle for voice communications, and that's OK. AT&T put together a wonderful voice network. It's very productive. (Telephone rings.) Turns out with voice communications, we are silent about one third of time, and that works fine for voice, but for data communications, we are silent almost 99.97% of the time. Just picture someone sitting there; this record going click click click click click, with a very high speed line taking that click. It generates eight bits of shhh (silence) and eternity later, he hit the next key. It's silent almost all of the time, so we couldn't waste communications capacity with a dedicated link from source to destination. So we needed new technology. And that's when I began to investigate what would a network look like that could support data, and out of that I came up and I created a mathematical theory for packet-switching networks for the Internet. And in fact here on the blackboard you see some of the results that I got. This is a key equation for network performance. It gives you the average response time, how long to get message through a network, and here is the way to optimally assign the capacity of the network, and here is the kind of performance you get. And there's a whole mathematical theory behind this. So I developed this. I published it. It became a book. I worked on it but nobody cared. I finished this in 1962; nobody cared. So I went to AT&T and I said, "Look, you ought to develop a data network to support data traffic." And they said it won't work, and they said, "Even if it does work we want nothing to do with them." And the reason they said that is because they had a voice network (that) generated a lot of revenue for them, and there was no data to send. The computers weren't talking to each other yet. So they foolishly said, "we want nothing to do with it."

你知道，通过网络，我们用声音建立了彼此之间的联系，当我们开始谈话和正在谈话时，整个链接，链接序列就全部用在了我们的谈话中。如果我拉一下这个，那条链接就浪费了。那时，语音通信的链接有大约三分之一的时间是闲置的；这也没关系。美国电话电报公司组合起了一个很棒的语音网络，这是非常有成效的。在语音通信中，我们大约有三分之一的时间在沉默，对语音来说没问题，但对数据通信来说，我们在 99.97%的时间里都保持沉默。想象一下有个人坐在那儿；录音哒哒响，速度极快的线路传送着哒哒声。它产生了 8 比特的静默，几乎在永久的沉默后，他按下了另一个键。在几乎所有的时间里，它静无声息，所以我们不能用一根从来源到目的地的专用链接去浪费通信能力。因此，我们需要新的技术，这就是我开始调查什么样的网络能支持数据，从这儿入手，我想到并为互联网的分组交换网络创建了一种数学理论。其实，在这儿的黑板上，你可以看到我得出的一些结果。这是网络性能的一个关键方程式，它告诉你平均响应时间、通过网络获得消息要多久；这儿是分配网络容量的最佳方式，而这儿是你获得的性能。这背后有一套完整的数学理论。所以我开发了这个并把它出版了，它成为了一本书。我投入了时间和精力，但没有人在乎它。1962 年我就完成了这一切；却没人在乎。所以我去了美国电话电报公司，跟他们说："看，你们应当开发一个数据网络来支持数据传输。"他们说这没什么用，说："即使它真有用，我们觉得这跟我们一点关系都没有。"他们这么说的原因是他们已经有语音网络，它为他们带来了大量的收入，也没有要传送的数据。电脑那时还没有彼此交谈，所以他们愚蠢地说这跟他们一点关系都没有。

（15:19）

In fact, I remember these conferences we used to go to, major computer conferences, and there'd be a plenary session. Ten thousand people in the audience. Two groups arguing with each other: the telephone guys and us, the computer guys. And we'd say, "Telephone network people, please build us a data network." And they would say, "What are you talking about? The United States is a copper mine. It's full of copper telephone wires. Use our network." And we'd say, "No, no, you don't understand. It takes you twenty-five seconds to dial up a call. You charge a minimum of three minutes, and we want to send a text of a second of data." And their answer was, "Little boy, go away." So we went away and created the Internet, and ate their lunch basically, but it took years. In fact AT&T finally came out with their premier packet-switching network in 1983, 14 years after we started this network.
事实上，我记得我们过去经常参加的那些会议，大型的计算机会议，会议中有一个全体大会，参与者有一万人。两组人群互相争论：搞电话的家伙和我们这些搞电脑的家伙。我们说："你们这些搞电话网的，请给我们建立一个数据网吧。"他们说："你们在说什么？美国是一个铜矿大国，到处是搭建电话线路所需的铜。用我们的网就行了。"我们说："不，不，你们不明白。拨一个电话需要 25 秒，你按三分钟起步来收取费用，而我们想要发送的文本只占一秒的数据。"他们的回答是："小家伙们，走一边去。"所以我们走到一边，建立了互联网，基本上把他们的市场份额占领了，但这个过程用了十几年。其实，美国电话电报公司最后在 1983 年推出了他们的第一个分组交换网络，那已经是我们开始自己网络的 14 年之后了。

And three years later they closed it down at a billion dollar loss. They couldn't do it. It's not an easy technology and you have to be prepared to understand the way it should work. Okay. So nothing happened in the early (19)60s. Meanwhile, separate timeline, (in) 1957 what happened? Russian was launching Sputnik. With many years there were earth observing satellites driving American crazy. President Eisenhower said, "We have lost the lead technology. The Russians are ahead and we have to correct that." So in early 1958, he created what's called the Advanced Research Projects Agency Department（ARPA）. And its job, as you probably think of, is to support science, technology, engineering, mathematics, drifting the United States back up to premier position in those domains. And so they started supporting research in provided scientific areas. In 1962 they began supporting computer research, and the first leader of that group was Licklider, a wonderful visionary at MIT. And they continued to support. And the leadership changed. The second one you have to Licklider, was gentlemen Ivan Sutherland, who had been a classmate of mine at MIT, and he came to UCLA in 1964. And he said, "Len, you have three identical IBM computers here on campus, (in) medical area, in the business area and for the campus. Let's connect them together. You know how to do it. So it's very easy to do that. They're identical computers." So I went around to the administrative offices for each of these computers, and he couldn't get them to agree. The bureaucracy, the jealousies, none of them wanted to share their computers. It didn't happen, but as a result, the idea of the network was now in the mind of ARPA that network has some benefits.

三年之后，他们停止了这个项目，损失了十亿美元。他们做不了，这不是什么简单的技术，你得做好准备，理解它的工作方式。好吧。所以二十世纪六十年代，什么都没发生。同时，在另一根时间轴里，1957 年，发生了什么？苏联发射了人造卫星。地球观测卫星存在多年，把美国人逼疯了。艾森豪威尔总统说："我们失去了领先的技术。苏联人领先了，我们必须把它纠正过来。"所以在 1958 年初，他建立了被称为高级研究计划局（ARPA）的机构，它的职责，就像你可能已经想到的，是支持科学、技术、工程、数学，让美国重新回到这些领域的领先地位。所以他们开始支持研究这些科学的领域。1962 年，他们开始支持计算机研究，这个小组的第一位领导者是利克莱德，他是麻省理工学院一位杰出而有远见的人。他们持续支持下去，领导者发生了改变。接替利克莱德的第二位领导者是伊万 萨瑟兰，他是我在麻省理工学院的同班同学，于 1964 年来到 UCLA。他说："伦，你们校园里有三台一模一样的 IBM 计算机，分别在医学院、商学院和行政机关。我们把它们连接在一起吧。你知道该怎么做，很容易的，因为它们是相同的计算机。"所以我在三个行政办公室奔走，但他们不同意这么做。出于官僚主义和嫉妒，没有一个部门愿意分享他们的电脑。所以没能把三台电脑连接起来，但是这件事后，网络这一主意在高级研究计划局（ARPA）形成了，他们觉得网络有它的好处。

A couple of years later, Ivan, his position was taken over by Bob Taylor. And meanwhile they had been supporting a number of researchers around the country, and giving them computers to develop good technology, and each one of them developed very specialized technology. For example University of Utah-excellent graphics, SRI-database technology; UCLA, simulation technology; University of Illinois, high performance computing, and they continue to go around and identify very good researchers, "So you are a good researcher? Here is a pile of money, we want you to do research in the area in which you are excellent." And the researcher would say, "Fine, buy me a big computer." And ARPA said, "Fine, we'll buy you a big computer." But by then the researcher would look around and say, "Look, there's really good graphics in Utah, and high performance computer in University of Illinois etc. I want all of that here." And ARPA said, "We can't give everybody all the resources, but if we put you in a network, (and) you want to do graphics, you (can) log on to the network and do graphics in Utah. Run like that, so we don't have to replicate everything." That was the motivating factor for ARPA building what we call the ARPANET which became the Internet. It was not to protect the United States against a nuclear attack by the Russians.

几年之后，伊万的位置被鲍勃 泰勒取代。同时，他们一直支持全国各地的许多研究人员，给他们提供计算机来开发好的技术，每一个研究人员都开发出了非常专业的技术。例如，犹他大学精湛的制图学、SRI 的数据库技术、UCLA 的仿真技术、伊利诺伊大学的高效能运算。他们继续搜寻，找出优秀的研究人员："你是优秀的研究人员吗？这些钱给你，我们想要你在自己最擅长的领域进行研究。"研究人员会说："好的，给我买台大型计算机吧。"ARPA 说："好的，我们会给你买台大型计算机。"但到了这时，研究人员会四下打量，说："看，犹他大

学的制图学非常好（伊利诺伊大学的高效能运算非常棒等等），我希望所有的好资源都能到这儿来。”ARPA 说：“我们无法把所有资源给到每一个人，但如果我们能让你联上网，你想要研究制图学，就可以登录到网络，在犹他大学研究它。这样的话，我们就不用复制所有资料。”这激励 ARPA 建立起了我们称之为的阿帕网络（ARPANET），后来它成为了互联网。它并不是用来保护美国不受苏联核攻击的。

（20:05）
BZ: That's what we heard.
LK: That's an urban myth. Now understand, I'm saying that from the point of view of one of the researchers, being supported by this office within ARPA. ARPA had a number of offices one was the computer group, and the idea was we're going to just do research and allow people to communicate and send two applications across to them. What the higher levels of ARPA said to the Department of Defense, to the President, we don't know. And that's where the urban myth came from, that perhaps it was really related to the defense. So the idea of making steps became now really a dominant issue of ARPA. And so ARPA brought in another classmate of mine, Larry Roberts as chief scientist to basically manage and fund this network. So he brought Larry to a bunch of us together, he was, as I said, not only a classmate who was office mate of mine at MIT, he knew exactly what I had done. So he brought me in to do the network measurement and evaluation, and others as well to help design the architecture of the network.
钟布：我们一直都以为是的。
LK：这是一个都市神话，现在你们知道，我是从研究者之一的角度来看待的，我受到 APRA 下面的这个办公室的支持。ARPA 有许多办公室，有一个是计算机组，他们的想法是我们就只做研究，让人们去沟通，给他们发送两个应用程序。ARPA 高层对国防部和总统是怎么说的，我们不知道。这就是都市神话的起源，也许它真的和国防有关，所以进一步研究的想法现在真的成为 ARPA 的主要问题。因此，ARPA 又引进了我的一位同学，拉里 罗伯茨，作为首席科学家，主要负责和资助这个网络。所以他让拉里跟我们一起研究。拉里，正如我说的，不仅是我在麻省理工的同学和办公室同事，而且他清楚地知道我研究过什么。所以他让我来做网络测量和评估等工作，来帮助设计网络的体系结构。

Now one of the people employed in, I mention like Lincoln laboratory before, (yes) Lincoln laboratory is a laboratory associated with MIT, just the way GPS for Cal-tech，Lincoln labs for MIT, the other people who supported all of my graduate work and also Larry`s multivariate of the islands. One of the people there who helped develop into the early computers was a fellow named Wesley Clark, at this meeting he said, “You don't want to take a host computer like this, and make it to all the networking, it's too much burden the people who own this machine won't do it, they don't want to be bothered, instead take all the networking complexity and put it in a separate machine that stands by.” What we call the IMP now and so we specify what IMP should do. We want the full spec, and among the components of the spec with things like this. We said, “Well, let's see if this is going to be a network that supports interact views. You'd better be able to send short messages very quickly.” So we said the response time on average the mean response time for a short message should be no more than half a second that would expect. It turns out we could do two tenths of a second easily as well. We all said it should be reliable. Well, how reliable? Well, there're various ways to specify the liability. One theoretical but not practical way to say it should be up and running 0.999 of the time. Well you can't really test that, we made it simply said the network should be, it should be such that if anything breaks a node or a lag, everybody else should still be able to communicate, that's called the two connected topology, specification. I was, er, I said this is an experimental network. We have to be able to measure it. We have to be able to generate traffic moving around, collect the statistics and evaluate. So all this one is this map the speck was then sent down to industry. Industry was asked to bid on building this network with the job to create the IMP, to deploy it at 19 sites around the country, to lease the lines between these IMPs, from AT&T, but take their circuits which is out and put on packet switches in and to keep the net working, went out to industry results came back and this around Christmas time of 1968. The contract was awarded to vote for like a new one. They want the contract that had good people there.

现在的员工之一在我之前提到的林肯实验室，它是与 MIT 相关的，就像全球定位系统和加州理工学院有关，林肯实验室和 MIT 相关；其他人支持我所有的研究生工作和拉里的岛屿多元论。其中有一个人叫韦斯利·克拉克，协助开发了早期计算机，在这次会面中他说："你不会想把这样的电脑做主机，并把它和所有的网络连接起来，负担太大了，这台电脑的所有者不会这么干的，他们不想总受到打扰。相反，可以把所有的联网复杂性放到一台单独的备用电脑上。"这就是我们现在称之为的接口信息处理器（IMP），所以我们明确了 IMP 的职责。我们想要完整的规范，在对像这样的事情的规范成分中，我们说："好吧，我们看看它是否会成为可以支持互动观点的网络。你最好能够极快地发送短信息。"所以我们说，对于一条短信息的平均响应时间，我们的期待值是应当不超过半秒钟。结果，我们可以轻松地把它做到五分之一秒内。我们都说这应该挺可靠的。有多可靠？有许多方法可以详细说明可靠性。一种理论上说得通但不可行的方法是，它应该高达 0.999。你没法真的去测试，所以我们简单地说，网络应当是这样的：如果缺了一处节点或者延迟，其他每个人应该仍然可以交流，规范地说，这被称为双重连接的拓扑结构。我说这是一个实验性的网络，我们必须能够测量它。我们必须能够生成可以四处传输的通信量、收集统计数据并进行评估。这一切都在这张地图中，然后被送到业内。行业要求通过投标来建立这个网络和 IMP，并把 IMP 部署在全国的 19 个点，从美国电话电报公司租赁线路来铺设在这些 IMP 之间，但把他们的电路取出来，放入分组交换机，让网络运行，在 1968 年圣诞前后得出了行业结果。我们得到了这份合同，并通过投票得到了新合同。他们想要出色的人来获得这份合同。

It's a smart move. It was not competitive, by the way, it was done by the committee, not a peer group. And their job with the deliver the first switch to UCLA in eight months over the Labor Day weekend, so from late this out best in early January to early September deliver. They did it. They delivered a new technology, new applications, new uses in eight months up and running, on time on budget. There’s no way you could never do that again. Also a wonderful job they did so it came here and now we had one

node and the schedule was, so here we are, here is UCLA, 67 is this machine, the IMP is over there and this line is the one I told you we sent a few bits back forward for a second. In October SRI 350 miles in the north they had a host computer called, also scientific cases but a different machine, 940. They got the IMP, and this line was installed.
这是明智之举。顺便说一下，这不是竞争，它是由委员会操作的，而不是同类群体。他们的工作是把第一台交换机在 8 个月内送到 UCLA，即劳动节前后。所以从 1 月初到 9 月初他们都在忙着这个。他们做到了。在八个月内，他们按时按预算交付了一种新技术，新的应用程序和使用。你永远不可能再这样来一次。而且他们做得非常棒，所以它来到了这儿，我们有了节点和安排。我们在这儿，UCLA 在这儿，这台机器是 67 号，IMP 在那儿，这条线路就是我告诉你们的、我们花了一秒钟来发送了几字节的。10 月，往北 350 英里的斯坦福研究所（SRI），他们有了主机 940，也是科学用途，但是是不同的机器。他们有了 IMP，安装了这条线路。

This is the first piece of the internet backbone, running at a blazing speed of fifty thousand bits per second, which is a trickle today. In those days that was blazing if asked and so it was connected and so we decided with the end of October to send the message from our machine to that machine to use the network exactly the way it was designed. Namely has someone sitting at a terminal logged onto this machine and request a log in to this machine through the network coming here and log on to that machine and then run an application. Now this machine doesn't necessarily know it to the network. It just sees uses coming in. That's another user now in order to do that this fellow has to log into this machine as if it's a local user. So all we wanted to do with that first message on October 29, 1969 was to log in. Now to log in you have to type L-O-G and the other machine is smart enough to know what you do. It will type I-N for you. So we only had to type three letters using this package which is in network. So I had my program here, Charlie Klein, this picture is over there I will show it to you later. And another program appeared named Bill, ready to do late one night October29, 1969. And we had a telephone connection between the two just in case so we could know what's going on.

这是第一条互联网的主干网，以每秒 5 万比特的惊人速度运行着，在今天，这不过是涓涓细流。但要是问起来，在那些日子，这个速度十分惊人。所以，它连接上了，我们决定到 10 月底，从我们的机器向那台机器发送消息，就按设计网络的精确方法来发送。那就是，让人坐在终端机器那儿，登录这台机器，通过网络要求登录；然后来这儿，登录那台机器，并运行一个应用程序。现在这台机器并不一定知道它已经联网了。它只是看到发来的运用。那是另一名用户，为了做到这一点，他必须登录到这台机器上，就好像他是本地用户一样。所以，1969 年 10 月 29 号，我们想要发送的第一条消息就是登录。要登录，你就必须输入 L-O-G，而另一台机器很智能地知道你要干什么，它就会为你输入剩下的 I-N。因此，用到网络中的这个程序包，我们只需要输入三个字母。我设计的程序在这儿，查理 ·克莱恩，这张照片就是在那儿的，我晚点带你们看。另一个程序叫比尔，是

打算在 1969 年 10 月 29 号深夜运行的。我们在这两台机器中间还有电话连接，只是以防万一，我们还能知道发生了什么。

(27:12)
Now you see the irony here. We were using a telephone network to create a new network which will displace the telephone network. The irony is beautiful. Okay, so we get ready, so we typed the L. Tony said, “You get the L?” Here said, “Yeah, I get the L.” Type O, “You get the O?” “Yep, I get the O.” Type G, “You get G?” Crash. The network is done so the first observation is what was the first message on the internet. “Hello” as in “lo and behold”. Now we didn't plan that. You know other great communications activities found as the pioneers have really good messages. Alexander Graham Bell and telephone, “I need you”. Samuel Morse, with telegram “What hath God wrought?” Armstrong, “a giant leap for mankind.” They were smart. They understood public relations, they understand PR and the media. We want that's fine, but we came up with the shortest, most powerful, most prophetic message we could. “Hello” as in “lo and behold” by accident and that happened at October 29, 1969 at 10:30 at night, but we didn't have a camera. We didn’t have a voice recorder. We only had one small entry in the log book and I'll show you in a few minutes which records what happened. But those in fact but just to continue their, this was this came in in September 1969, October 1969. This one came in November 1969, and this one December 1969, UC Santa Barbara and university of Utah. And then we paused and we now have a slightly interesting network so we could test it out rather than trying to break it. It was our job in UCLA as I said we were the network measurements. It’s our job to try to find faults or this natural so they can be corrected.

这儿你能看见铁。我们过去是用电话网来建立新的网络，再用它取代电话网。铁很漂亮。好，我们做好了准备，输入 L。这边说，“你收到了 L 吗？”那边说：“是的，收到了 L。”输入 O，“你收到了 O 吗？”“是，收到了 O。”输入 G,“收到了 G 吗？”网断了。网络搭建完了，所以首先观察一下互联网上第一条消息是什么。就像在“哎呀你瞧”中的“Hello”。我们并没有任何计划。你知道其他伟大的通信活动中，先驱者都准备了很好的信息。亚历山大·格雷厄姆·贝尔的电话：“我需要你。”塞缪尔·莫尔斯的电报：“上帝创造了何等奇迹！”阿姆斯特朗：“人类的一大步。”他们都很聪明。我们希望一切都好，但我们想出了最短最有力最先知的信息，“Hello”，它完全是在 1969 年 10 月 29 号晚上 10:30 分偶尔想到的。可我们没有相机，也没有录音机。我们只有一本小型日志条目，几分钟后我会展示给你们看，这本日志记录下发生了什么。但那些其实只是……继续看，这台机器是 1969 年 9 月到的，这台是 10 月，这台是 11 月，这台是 12 月，来自加州大学圣芭芭拉分校和犹他大学。然后就停了。我们现在有了个有趣的网络，所以可以对它进行测试而不是打破它。这是我们在 UCLA 的工作，我们是网络测量师，我们要努力找出错误并纠正它们。

BZ：Right. So back then and when you have this one crashing in your test. So how soon you'll find the bond?

LK：Less than an hour and I'll tell you what they're both was. It wasn't our machine; there wasn't ours switch. It wasn’t in the line, it wasn't in the switch of the SRI machine. I’ll tell you why. So first of all that wasn’t our fault and it wasn't our network's fault. It’s SRI’s fault. And the vision was this. When a local user comes in, the speed of light delay. It’s just, you know, a few nanoseconds. Four hundred, three hundred fifty miles is a much longer delay and so this machine which expected a response type of character gives a response topic，expected much more rapid time's here than we got here. So it's time I’ll say too small and we got a buffer overflow and then buffer of the machine. All we do is increase the timing on this and born. Okay, so that was the time and it got money very quickly.
钟布：好的。所以那时，这台机器在测试中崩溃了，多久才又重新连接上的？
LK：不到一小时。我来告诉你它俩都是什么。它不是我们的机器，也没有我们的转换器。它不在线路中，也不是 SRI 的转换器。我来告诉你为什么。首先，它不是我们的错误，也不是我们网络的错误，而是 SRI 的错误。情况是这样的：当本地用户上来时，光的速度会变缓，只是几纳秒。而 350 英里则是长得多的延迟，所以这台机器能给出一个回应话题，所用时间比我们抵达这儿的时间快得多。所以我们有一个缓冲区溢出，然后是机器的缓冲。我们要做的一切就是增加时间，所以那时就是这样，也很快就获得了资金。

BZ: I knew I really appreciate that I got to do a moment ago you mention that I get the two words L-O. Was that the real meaning there?
LK: Well, lo and behold is what it means.
BZ: Yes and what you say it's still meaningful but you know you just only two letters.
LK: Oh I’m extended I’m taking the liberty. Lo and behold. That’s the Bible. Exactly the Bible and it means look what's here. It’s all of what you use. So it was, we're extending it but it's an easy way to remember, and most people don't know that. With the documentary that came out by very hot stock. It’s spreading. When you see the average person that walks down this hallway, none of them know the first message leave. They haven't even asked what was it. They haven't thought to ask that question. Most people know what Armstrong said or even what Alexander Bell said. They learn that at school. You know so it's an interesting question why not and some of the answer is that the children of today grow up with the internet. It’s been here forever like oxygen, so you know when the oxygen start it's silly questions. (Take it for granted.) They take it for granted in this case, but it's getting more and it's very likely ended up with a very simple message. So let me show you a few more things. Actually Charlie is not in this picture, he's in another picture. This is our machine, this fellow is John Pastal. He was one of my graduate students here and he read the domain name system for decades for the internet. He since passed away. That's one of our technicians. This I believe is the digital equipment except the scientific data systems engineer for this computer. And this is one of my staff as well. That's me back then and we have some other pictures around. I think Charlie as well at any rate. This is an example of a kind of terminal use.

BZ：我知道，我特别佩服。你前面提到的，我听到了两个字母 L-O。它们在那儿真是这个意思吗？
LK: Lo and behold 就是它字面上的意思。
BZ：你这么一说，它的确是有意思的，但它们只是两个字母……
LK：我擅自把它的意思延伸了，Lo and behold. 这是《圣经》里的语句。它的意思是，哎呀，你瞧。我把它用到了这儿。我们延伸了它的意思，但这很容易记住，而大多数人不知道它。有纪录片记载，让它被更多的人知道。你看到走在走廊上的普通人，他们没有一个知道第一条消息。他们甚至不会去问第一条消息是什么，也从未想到过要问这个问题。大多数人知道阿姆斯特朗说的，甚至知道亚历山大·贝尔说的，他们在学校就学过。所以这是一个有趣的问题，不是吗？某个答案是，今天的孩子是和互联网一起长大的。互联网就像氧气一样一直存在着，所以你要是问氧气是什么时候开始有的，这就是个愚蠢的问题。（人们把它当成理所应当的了。）在这种情况下，他们把它当成理所应当的了。但这越来越多，很可能就以一则非常简单的消息结束。我再给你看看更多的东西。实际上，查理不在这张图片里，他在另一张照片里。这是我们的机器，这个同伴是约翰·帕斯塔尔。他是我的研究生，读了几十年的域名系统，现在已经去世了。这是我们的一位技术人员。这个，我觉得是这台电脑的数字设备，没有科学数据系统。这也是我的员工之一。后面那个是我，我们还有一些其他的照片。查理应该也在那些照片里。这是一种终端使用的例子。

BZ: I’d like to um quickly identify the yellow shirt and it doesn't have you have a favorite that's color. All this is yellow is your favorite hotter?
LK: I like you very much and it's different. A lot of people with blue white, I like you.
BZ: Okay, sorry for interrupt but I just can't help noticing the color.
LK: This is still my same office by the way ever since I came here in 1963.
BZ: Right, that's what we have another question how we must have maybe a moment later and I’ll ask you since 1963 you came here and I believe you there's so many temptations to bring you to Washington DC, or bring you back to MIT or somewhere else. (yeah) But you always stay like you say.
LK: Well, I love teaching for one thing you know, the way I took this job is rather interesting. MIT Lincoln laboratory sent me to MIT from my master's degree and that's all I wanted to get. My son was born, it talked me to get in the PhD. They funded everything, they provided to pay my tuition, my living expenses, salaries. Now I wanted to work with them, and they wanted me to work with them. But they have a policy: before people on scholarship work for them, they want them to look out around the world and see what else is out there. So I took a tour around the country, east coast, west coast, tons of very good places. By accident you see I thought I wanted to have a position but haven't set up. They interviewed me and gave me the offer. And now I had a problem. You know this looks like a very interesting job. I’ve done a little bit of teaching, very little at MIT and I liked it. Basically you don't have a boss, you did the research you want. You work with young people, right minds, colleagues from all over the world come to the university on visits. You get to travel a lot and it's doing good, it's a good responsible job. So I went to Lincoln like I said. I really want to work here but this is not the offer. All the way across the country in those days that was like the wild

west. And they want to pay me half the salary. I’m getting your Lincoln lab, doing something that I’ve never done before, away from family and friends. But it looks interesting and their answer was beautiful. They said, “Try it, if you don't like it, come back.” What a wonderful offer, very generous. I came here. In 54 years later I’m still here because I do like both teaching and research and working with young people, because it keeps you young, mentally and physically.

BZ: But if you go back and you know teacher at MIT that's the same. You still interact with the young people.

LK: Well there was some personal reason I wanted to say. It had to do with the family. I won't go into that but there were other reasons. And I love, you see, a great great environment, great colleagues, and I was working with students. I’ve generated almost fifty PhD students. A small army of network experts across the world all countries. And so I just love that, created generations. So let me show you the log here. This is in October shortly after the hurricane, we decided to keep a log. Why? Because John Pastal, one of my graduate, said he had to keep a record of what's going on here and he was like the disciplinarian. So we started this thing on October 9. but too shortly nothing after the case and you see his first entry, you see that's John Pastal, and he's talking about things and there's some wonderful little entries here let me see if I can find it, really cute. This is by John. It was on October 14, “The above is unreadable and not signed. Please try harder.” He's telling these people to be disciplined. But the most important entry is ah related, it's right here, on October 29, 1969 at 10:30 at night, “Charlie made the entry talked to SRI host to host, computer to computer.” That's the only record of that LO message we sent and I consider this perhaps the most important document of the internet.

BZ: Very much so. This is the start of the revolutionary. Like you said that, to the minute.

钟布：我认出了那件黄色的衬衣，你有最喜欢的颜色吗？黄色是你最喜欢的颜色？

LK：我非常喜欢你，这不一样。许多人喜欢蓝色、白色。我喜欢你。

钟布：不好意思打断你了，我实在是没忍住注意到了这颜色。

LK：从我 1963 年来到这儿后，这一直而且仍然是我的办公室。

钟布：是啊，等会我们还有个问题，但我想问问你，从 1963 年你到这儿之后，你一定面临很多诱惑，去首都华盛顿，或让你回到 MIT 或是去其他地方。（是的）但如你所说，你一直待在这儿。

LK：一方面是因为我热爱教书；我得到这份工作的方式相当有意思。MIT 的林肯实验室在我获得了硕士学位后让我去 MIT，这其实是我想得到的全部。我儿子那时出生了，经过一番交谈，我决定攻读博士。他们资助了一切费用，我的学费、生活费和工资。现在我想加入他们，一起工作，他们也想让我跟他们工作。但他们有一条政策：在奖学金获得者想加入他们工作之前，他们要这些人出去走走，看看世界，了解学校以外的地方。所以我去全国旅游了一趟，东海岸，西海岸，无数非常美好的地方。偶尔我会觉得我想要工作，但位置还没设定。他们面试我后给我提供了工作机会。现在我遇到了一个问题。这看起来是一份非常有趣的工作。我教过一段时间的书，在 MIT 的时候，感觉自己很喜欢教书。基本上你没有老板，你可以做自己想做的研究。你和年轻人、拥有正确思想的人一起工作，

你有从世界各地来大学当访问学者的同事。你要经常出差，这挺不错的。它是一份责任重大的好工作。所以如我所说，我去了林肯实验室。我的确很想在这儿工作，但这不是我的工作机会。那些日子我在全国旅游，就像在荒无人烟的西部一样。他们打算付我一半的工资。我来到了林肯实验室，做了一些我从未做过的事，远离了家人和朋友。但它看上去很有趣，他们的回答也很动听。他们说："试试吧，如果你不喜欢，就回来吧。"这个工作机会太棒了，十分慷慨。所以我来到了这儿，54 年之后，我仍然在这儿，因为我的确喜欢教书和做研究，喜欢和年轻人一起工作，因为它能让你保持心理和身体上的年轻。

钟布：但如果你回去，在 MIT 教书，也是一样的。你仍然可以和年轻人交流互动。

LK：有某个个人原因，和家庭相关，在这里我不多说，但是是有其他原因的。我热爱这儿，环境很棒，同事非常好，我和学生一起工作。我已经培养了大约 50 名博士，他们在全世界、全国成了网络专家。所以我就是热爱这一切，去培育一代代的专家。来看看这儿的日志吧。在 10 月飓风后不久，我们决定写日志。为什么呢？因为约翰 帕斯塔尔，我的研究生之一，说他得把发生在这儿的事情记录下来，他就像维持纪律的人一样。所以我们从 10 月 9 号开始了记录。但在飓风之后都没发生什么事情，你看这是他写的第一条，这是约翰 帕斯塔尔，他在谈论一些事情。这儿有一些精彩的小条目，看看我是否能找到，特别可爱。这条是约翰写的，日期是 10 月 14 号："以上记载难以理解，而且没有署名。请更加努力。"他在告诉这些人要遵守纪律。但最重要的条目在这儿，1969 年 10 月 29 号晚 10:30 分："查理正式和 SRI 的主机连接上了，主机和主机、计算机和计算机进行了交谈。"这是我们发送的 LO 信息的唯一记载，我认为它也许是互联网最重要的文件。

钟布：千真万确。这是革命的开始。就像你说的，一点都不差。

(37:24)

LK: Now you may wonder how come I can handle put my fingers all over this. Of course, this is not the original. This is a beautiful replicate, almost identical. You can't tell.

BZ: Right. Where is the original?

LK: The original is hidden away hermetically sealed archive with UCLA and one of my post-doc who began to work before, he saw me handle it. He's a historian. He saw me handle this, he took it away. So now I can handle here. And here's some pictures of some of the other people. This is Paul Baron, he worked on this little bit after I did. That's Larry Roberts. That's myself. That's a picture of me that came out of my book. That's an interesting book. And that's Donald Davis who worked later in the UK. (Yes, Donald Davis, yes we know that.) And both Donald and Paul passed away. There is a record of sputnik, there is a little bit stuff. Now this is an example of the final technical report over this period, when we were working on with this technology. And this is the BBN group. This is Bob, and there's Frank Hard. He was ahead of that group and you can see here is an IMP. Here is another one; they were testing them and they began to deploy them. Here are some articles, one is that topology. Here is one that I wrote on a little design. Here is one buddy BBN guys. Here is somebody that might crack a surf.

Are you going to visit crack also? (Yes.) Good. These two work for me in my software group along with Charlie Klein.

BZ: Where is your queuing theory?

LZ: In the books in my office, but the queuing theory was the key to use to analyze the system, and the queuing theory is a very esoteric mathematical discipline. Why would anyone ever want to study it? Persistent exactly, the two teams were evaluated. It talks about response time to put efficiency, storage and buffering throughput. So those quantities are exactly what you want to talk about a network and it's a very effective theory. In fact, because I used it and I extended it for my own research that launch an entire field of research in using queuing theory to evaluate computer systems, timeshare systems, computer networks, mobile networks, internet of things etc. And there's a fair slim of chance now. And the way you spell the word “queuing”, it’s two ways to spell it. (With E and without E, right?) Exactly. With the E is the British way and with the E get five vowels in a row and no other word in English has five vowels in a row so it's very special one. (Thank you. Thank you for that we know that that's good.) Here is a bell telephone and here, this is… It’s a pocket protector. Put it in your pocket. Well you would put in your pocket, and then you put the pen in here. It doesn't make your pocket … (Ok, all right.) This was used by a lot of the engineers back in my period in the sixties. In fact, have you seen the movie Hidden Figures? The female heroine is Vanessa. Exactly. There's the scene when she walks into this room full of engineers carrying her box and she looks around for places sit down and who is in the room people dressed almost like you: white shirt, short sleeves, black narrow, black tie, pocket protector and crooker. That was me this was exactly that kind of course I will but I have other pictures of me like that too. That's was a very accurate description, but anyway this is. So what else can I show you here? (That machine you didn't mention.) That is that that's a teletype yeah it's a kind of terminal we used to connect to this machine and other ways to work as an example of one of those early teletypes. (Does it still work?) No. You can’t get this to work. But it would do. It would print on this roll of paper and punch out paper tape. Basically it goes this way. We use a lot of paper tapes in those early days.

BZ: You start from here like LO log in?

LK: It wasn't this machine. First you have to set up a connection there, you have to let that machine in know you're trying to talk its host. That's called the initial connection protocol. Once you have that then you can talk to the host as you logged in. (Do you have like a password to protect?) None at that time. (You don't need one because that's the only other computer.) That's a very powerful question you just asked. In the early days who wanted to use in network? Most people wanted not to use the network. Suppose you want a big computer say in the university of Utah. We come to you saying, “Please connect you and your computer into our network.” “Why?” “So we can use it.” “What are you talking about? My people need a hundred percent of the use. You can't have any.” We said, “but you can use other people.” “No, I don't want.” So there's a lot of resistance. So what I did in those early days as I went to every nineteen nodes and began with the nineteen LO network was, it’s not showing you. One of my papers I can show you. It changed along the way; it was between these two networks. When every one of the sites and I said, "Would you like the network use?" "No." "So how about the using two teletypes with it?" "Okay." "And how much do we use the network?" "I have no idea. Three teletypes…" So I got them each to explain what they might use and then I publish the paper I think it's among the journals over there and I showed the network and the traffic in each one said they were used. And now they were forced to use it but they still didn't want to use it for a number of reasons. Why? They didn't want to use, let other people use their machine. It was difficult to use somebody else's machine as you said. You have to get notified us to use that we had to get basically credentials here, needed a login, needed to know the command language, needed to know how to run the applications… Big impediment and so it was our job to try to convince people to use the network. So an entity of question we didn't put any words, restrictions, common uses make it very easy. And in fact it was so. (I'm trying to imagine like fifty years ago you logged in your computer, how difficult to use it because they have different setting, software…) You have to know, you have to learn. And so what was the early use? First of all, not only that but there was no easy way for a host to talk to another host. So until we got something called a host protocol, which came out in 1971, it was a very complicated. So who would use it? Suppose there's a researcher here, a graduate student and he takes a job at UCLA. He knows how to use that machine better than he knows how to use this one. So that kind of traveling around the using in the early days, there was very little traffic in the early days until a host protocol came out and then it began to pick on. (So their first PDP is ten we saw that. You know PDP one.) PDP ten was a very popular machine on the internet on the early ARPAnet. So popular that all the stuff finding these machines and push people to put other machines on like IBM, like CDC, etc. So that was a rather interesting development. In fact I'm not sure if any of these pictures show the machines. Oh, the map that shows exactly what was in. Here is only the names of the sites. By the way, this is that network and there is the first line. There it is, there it is, there it isn't, which means someone was thinking we would think it very hard about that topology. It's not obvious what to do; you have to think about what the traffic was in all the rest. So it's easy to put lines in; it's hard to take them out for me. Responsibility to and you know these never grew. They got more complicated. I'd like to say that design in the topology of network you can't do it on the back of an envelope but that looks like the back of an envelope. And it grew and grew. The number of sites has been growing exponentially since the day. (You have the real copper lines to connect this kind of dots, right?) Some of them are microwave. They were AT&T lines. We leased lines from AT&T on a special government tariff, but they were using voice switches called circuits, which we took them out and we put our switches into the package. We didn't lay any lines at all. (Okay, so that's not always the phone line; it's sometimes like you said, the microwave.) Yeah, well, microwave would support phone as well. What you call phone wires, it was copper it was microwave those days. Now it's five collected over the left and satellite as well. We have satellite links coming in rather early. It's not shown in these networks here but was around this time that we send the satellite link across to England in Norway. And here is the satellite.

LK: 现在你可能在想我怎么能用手来摸这本日志的。当然，这本并不是原件，它是一本精巧的复制品，跟原件几乎一模一样，你分不出真假。

钟布：是的。原件在哪里？

LK：原件藏在 UCLA 档案馆中，密封保存起来了。我的一名博士后，在这儿工作之前，看到我想处理它。他是一个历史学家。他看我想处理它，就把它拿走了。所以我现在可以在这儿拿着这本日志。这里还有其他一些人的照片。这是保罗·巴伦，在我来这儿之后，他也在这儿做了一些工作。那是拉里·罗伯茨。那是我。那张照片夹在我的一本书里。这是一本有趣的书。那是唐纳德·戴维斯，后来在英国工作。（是啊，唐纳德·戴维斯，我们知道他。）唐纳德和保罗都已经去世了。这是苏联人造卫星的记录，这儿是一些其他的东西。这是这段时期最终技术报告的范本，当时我们在研究这项技术。这是 BBN 小组，这是鲍勃，这是弗兰克·哈德，他是那个小组的负责人。这儿是 IMP，这是另一个 IMP，他们在测试它们，并开始对它们进行部署。这儿有一些文章，其中一篇是拓扑学。这儿是我写的一个小设计。这是 BBN 小组的一员。这两人是跟我一起工作的，和查理·克莱恩一样在我的软件小组。

钟布：你的队列理论在哪里？

LZ：在我办公室的书中，但队列理论是分析这个系统的关键，它是一个很深奥的数学学科。为什么会有人想要学习它呢？持久性，的确，有两队进行评估。它谈到了把效率、存储和缓冲吞吐量放在一起的响应时间。所以这些量正是关于网络你想要谈论的东西，它是非常有效的一种理论。事实上，我使用过它，因此将它延伸到自己的研究中去，从而开始了使用队列理论来评估计算机系统、分时系统、计算机网络、移动网络、物联网等整个领域的研究。现在很少有研究空间了。你有两种方法来拼写“queueing”。（一种词末有 e，一种没有 e，对吗？）完全正确。英式英语中有 e，那就是五个元音排在一起，在英语中没有其他任何词是五个元音排在一起的，因此它非常特别。（谢谢你让我知道这个，这个挺好的。）这是贝尔电话，这是一个口袋保护袋。把它放在你的口袋里，然后把笔放在这儿。它不会磨坏你的口袋。在 20 世纪 60 年代，很多工程师都在用它。你看过那部《隐藏人物》的电影吗？（女主角是凡妮莎的那部？）完全正确。有一幕就是当她拿着盒子走进满是工程师的屋子时，四处张望想找个地方坐下来。屋子里的人们穿着和你几乎是一样的：短袖白衬衫、黑色窄领带、口袋保护袋和钩子。这个是我。当然，我有其他照片，和这样的穿着是一样的。这个描绘非常准确，不管怎样，就是这样的。我还有什么可以向你们展示的？（你没提到那台机器。）那是电传打字机，它是我们用来连接这台机器的终端，它是早期的电传打字机之一。（它现在还能运行吗？）不能了，它没法用了。但这台可以用。它能在这卷纸上印下字，输入纸带。基本上这就是它的工作原理。早期我们使用了大量的纸带。

钟布：你是从这台机器上输入 LO 的？

LK: 不是这台机器。首先你得建立连接，你得让机器知道你打算和它的主机交谈，这被称为初始连接协议。一旦你有了它，就可以登录进去，和主机进行交谈了。（有没有像密码一样的东西来保护呢？）那时什么都没有。

钟布：你不需要密码是因为这是唯一一台连接上的机器？

LK: 你刚刚问的是一个很有力的问题。早期，谁想联网？大多数人都不想用网络。设想一下，假如你在犹他大学有一台大型计算机。我们来找你，跟你说：“请把你的电脑连入我们的网络。”“为什么？”“所以我们也可以使用它。”“你在说什么？我的人需要对这台电脑有百分之百的使用权，没法让你们用。”我们

说："但你也可以用其他的啊。""不，我不想。"所以阻力很大。那么早期我干了些什么呢？我去了 19 个节点，从这 19 个节点开始联网，这里面没有展示出来。我写了一份论文，上面有。它一路发生了变化，在两台联网的机器之中。我到每一个节点都会问："你想要联网吗？""不要。""那用两台电传打字机连起来呢？""可以。""我们可以使用多少网络？""我也不知道。"所以我一个个地跟他们解释他们可能会用到的，然后我出版了这篇论文，它应该在那边的期刊中；我向每个说他们会使用的人解释了网络和通信量。现在他们被迫使用网络，但仍然有各种各样的理由不想使用它。为什么呢？他们不想让别人使用他们的机器。如你所说，很难使用其他人的机器。你必须通知他们，我们必须得到基本凭证，需要登录，需要知道命令语言，需要知道如何运行这个应用程序，障碍很多。所以我们的工作就是努力说服人们使用网络。对于各种问题，我们并没有用任何词、限制、常见使用来让它变得容易起来。实际它就是如此。（我努力地去想象 50 年前，你登录进自己的电脑，使用起来有多么难，因为它们有不同的设置、软件……）你必须知道，你必须学习。那么早期使用什么呢？首先，不仅如此，而且没有什么简单的方法能让主机和另一台主机进行交谈。直到我们有了主机协议前——它出现于 1971 年——都是非常复杂的。谁会使用它呢？假设这儿有一个研究员，他是研究生，在 UCLA 工作。比起这台机器来，他更知道如何使用那台机器。所以早期这种各处奔走的人，早期很少的通信量，在主机协议出来后，才开始增多的。（所以他们第一台 PDP 就是我们看见的十号。）PDP 十号在早期的阿帕网中是一台非常受欢迎的联网机器。它很受欢迎，所有的东西都和这些机器相连，让人们把其他机器也加入进来，像 IBM、CDC 等等。这是很有意思的发展。事实上，我不知道这些照片中有没有这些机器。哦，那张地图上有它。这儿只是那些节点的名称。另外，这是那个联网，这是第一根线路。这儿也是，这儿也是，这个不是，这意味着有人在想我们会觉得拓扑很难。要做什么并不明显，你必须考虑所有其他机器的通信量。所以对我来说，铺入线路很容易，把线取出来很难。你知道它们永远不会发展了，它们越来越复杂了。我想说，你不能在信封背面进行拓扑网络的设计，但那看上去像信封背面。它不断发展，网点的数量从那时起一直呈指数级增长。（你有真正的铜线来连接这样的站点，对吧？）有些站点是用微波连接的，它们是美国电话电报公司（AT&T）的线路。我们用政府特别关税，从 AT&T 租用线路，但他们用的是语音开关，被称为电路，我们把它们取了出来，把自己的开关放了进去。我们完全没有铺设任何线路。（好吧，所以这些线路不全是电话线路，有些，就像你说的，是微波。）对，微波也能支持通话。那时，我们说的电话线是铜线和微波。现在我们有了卫星。我们比较早地使用卫星来连接了。这些联网中并没有体现，但就是在这个时候，我们把卫星连接发送到了苏格兰、挪威。这就是那颗卫星。

（48:44）

BZ: I'm just wondering why we go so long until then we get to see MIT?

LK: Just a few months MIT. These two were the first cross country lines, so by the next summer we had them. (High rise, very quick. It grew rapidly. Oh this is very beautiful, this is wonderful ARPANET.) I've got dozens of these pictures as a group. Okay here's an example of traffic between some of these sites in out that we developed by getting these people to assign how much they're willing to use the network. Something about measurements. We have all kinds of paper there. I have over two hundred fifty papers talking about the design. Yeah here's the traffic matrix and that's the original nineteen node network that would BBN was supposed to deploy and now it's a traffic between those nodes.

BZ：Can you show us the paper earlier that you put in the office?

LK：Yes, I'll show you them. This is 1969, but I did the original publication in 1962. We felt this is an extension. So that's pretty much of it. (But one more question is why you guys so handsome until today?) Here you see some of the computers attached and seventy five. These are the machines and there were many PDP tens. But we force IBM machines, we put some with machines, a number of others are HP, Illinois at Univac. That machine, TX 2, one of the first transistorize machines that's the one which I did my heavy simulation, I did the theory, I had approved the theory of work, so I simulated an exact network and measure how it performed compared to my theoretical predictions anyway. Why not?

BZ: So all these machines were sort of like not by the universities, funded by the government?

LK: Mixed. Some of them already had it funded from others, NSF, university itself, donated. They were connected but the number of the machines were support were funded by dogma.

BZ: Could you imagine those days like you have one of the machines in your own house?

LK: Well, actually we had these portable terminals. They were portable terminals. It was something called TI, seven hundred Texas instruments. It was like a big typewriter with yellow paper which had a modem in them and you could use a modem to connect to your machine then to the internet. And in fact I believe that I probably committed the first illegal use of the internet. 1973 in September it was a meeting in the university of Sussex in Brighton in England on computer communication so I went and they put us up with the dormitories at the university. It's a very good meeting; we talked about many things. I came home with day early and I'm unpacking and I realize I left my electric razor in the dormitory room and I want it back. The meeting was still going on, so I want to contact somebody there and I wanted to use the internet. This is 1973; it was very early. I said what crazy person would be on the internet now because it was 3 am in London. It was you know early evening in LA, so I said maybe Larry Roberts, my good friend. So I fired up in my home in my bedroom on one of these portable terminals and I tried it for a program called resource sharing executive. I was extract a problem that new it lived in a network and I just I didn't wear Roberts what it did it logged on to every machine and the network that many machines a few dozen and it looked at the coolest who was logged on right now. While I check what finally about three minutes later it says Roberts logged on to BBN in Cambridge mass. He was going out in Briton across the ocean to Massachusetts and so I set up a little chat session with him and I said I want it back. The next day I got a pack from Danny Cones with the name rarely known. He was one of the early pioneers also. (So they found the razor?) and brought it to me the next day. And now the reason it was illegal because the network was a research network for engineering research purposes not for personal use. Maybe it was the first illegal use.

BZ: So as a moment's the internet is only for research.
LK: Who was using it? Researchers. The public couldn’t use it. Businesses couldn’t use it and the government couldn’t use it as well. And that persisted for many years.
BZ: Was it also specifies that it's only for research progress?
LK: No, no. It was an unwritten policy.
BZ: Okay, it was substitute with ethics.
LK: Well, you bring up another very good point. The point is this: what was the culture? The mental view as to what was going on here, and it was a community of researchers and graduate students, and some ARPA program manages who were trying to accomplish something, created new technology. We were not trying to make a business; nobody got patents. We will do it because it was exciting, a hard project, interesting. And if I develop something that you used, that's what gave me the gratification. And that's all it was. And basically I knew everybody on the internet at the time. We had a booklet with all the email addresses once email was in, so we know how to reach every one of them, and they're well behaved. The culture was one of openness, free access sharing ethics, you know good network etiquette. And how did that culture come about? With research, community gratitude’s in faculty, that's not unnatural. It’s natural that but it was heavily basically enhanced by ARPA. ARPA had a wonderful funding philosophy. They come to you and say, “Look, I know you have a good researcher. Here is a pile of money. Go do something good in the area you're good at and I can't tell you what. Remember I say now I just wanted to live up the country and we know you're good. Go do something.” He has money for a long time. “Do something great, not small, great. Fairies are okay.” In a shoot high, what we call high risk, high payoff. Internet is one example. So the idea was…The government said, “we're not gonna bother you. Go do what you want.” Okay, so they come to me, said, “Here is the money. Go do what you want.” What am I gonna do? I come to my graduate students and according to say look we had the following things to do. We need a hostel protocol. Here is much money. Go do it. I’m not gonna tell you how. Come to me for advice if you want, but use your brain. And so the idea was openness, freedom, creativity, camaraderie. So we didn't put in any restrictions on use and the negative effect of that was we put in no protection. We didn't have to protect ourselves from each other. We should have put something because in 1988 the first worm appeared. In 1994 the first spam message came. And then the dark side of the internet began. We should have put some tools in the early days too in particular and turn them off until we need them, but we didn't put them in, so it's very difficult now to basically get a secure in it and there's a serious problem you know.
钟布：我很好奇为什么经历了这么长时间才看到 MIT 起了作用？
LK：其实就几个月。这两条是最开始的两条横穿整个国家的线路，到第二年夏天，我们已经弄好了它们。（速度真快，发展迅猛。这个很漂亮，这是美妙的阿帕网。）我有很多这样的图片，它们是一组图。这儿有个示范，说明了一些站点之间进出的通信量，这是我们让这些人说明他们有多愿意使用网络来得出的结果。这是跟测量相关的东西。我们这儿有所有种类的论文。我有 250 多篇论文是讨论设计的。这儿是流量矩阵，那儿是最初的 19 个节点网络。BBN 公司应当进行部署，现在它是节点之间的通信量。

钟布：你能给我们展示一下你放在办公室里的早期那些论文吗？

LK：当然，我等会就拿给你们看。这是 1969 年，但我在 1962 年就发表了论文。我们觉得这是一种延伸。关于这里，就介绍得差不多了。（还有一个问题，为什么你们现在看起来还是那么帅呢？）（笑声）这儿你们看到的是相连的一些计算机和 75 号。这些是机器，有许多型号是 PDP 十号。我们也有 IBM 的机器，和这些放在一起，其他很多机器是伊利诺斯州惠普公司的通用自动计算机。那台机器，TX2，是最早的晶体管机器之一，我用它做了大量的模拟，尝试了理论，证明了工作原理，所以我模拟了一个精确的网络，并与我的理论预测相对比，测量它的性能。为什么不呢？

钟布：所有这些机器都不是由大学、而是由政府资助的吗？

LK：都有。有些机器是由其他机构资助的，美国国家科学基金会、大学，还有些是捐助的。它们都已经连接在一起，有不少机器是由 DOGMA 资助的。

钟布：你能设想一下，在那时，你自己家里有一台这样的机器吗？

LK：其实我们有便携式终端机器，有时被称为 TI（德州仪器），700 台德州仪器。它就像一台大的打字机，上面有黄色的纸，里面有调制解调器。你可以用调制解调器连接到你的机器，然后再连接到互联网。事实上，我觉得我可能是第一个非法使用互联网的人。1973 年 9 月，在英国布莱顿的苏塞克斯大学举行了一次计算机交流会议，我参加了。他们让我们这些参会者住在宿舍里。这是一次很棒的会议，我们讨论了许多事情。我提早一天回了家，到家收拾行李时，我意识到自己把电动剃须刀忘在了宿舍，我想把它要回来。会议还在继续，我想跟那儿的谁联系上，这时想到了使用互联网。这是 1973 年，互联网早期。我说哪个疯狂的人此刻会在网上呢，因为那是伦敦时间凌晨 3 点，在洛杉矶是傍晚时分。我说也许拉里 罗伯茨也许在，他是我的好朋友。所以我在卧室的一台便携式终端上发送了消息，尝试了一个叫资源共享主管的程序。我提出了一个网络上从来没有过的问题，并没有指明让罗伯茨回答，只是发送了指令到网络上的每台机器，看看谁登录了。总共也就十几台机器，它查看了登录名单，看看谁现在登录着。最后，三分钟之后，程序说，罗伯茨在剑桥的 BBN 登录着。他在马萨诸塞州大洋彼岸的布莱顿，所以我跟他聊了一会天，告诉他我想要拿回自己的电动剃须刀。第二天，我从丹尼 科内斯那儿收到了它，这个名字很少有人知道，他也是早期的先驱之一。（所以他们找到了剃须刀？）嗯，找到了，还在第二天就给我送来了。现在说起来这是非法的，因为那时网络是一种用于工程研究的研究网络，而不是供个人使用的。也许这是第一次非法的使用。

钟布：所以那时互联网只能用于研究？

LK：谁能使用它？研究人员。公众不能使用，企业不能使用，政府也不能使用。这种情况持续了很多年。

钟布：它是否指定了只能用于研究发展？

LK: 没有，这是不成文的政策。

钟布：它是道德的替代品。

LK：你提到了一个很好的观点，这个观点是：文化是什么？这儿发生的事情，从精神观点来看，这是一个由研究人员和研究生组成的社区，还有一些 ARPA 项目经理努力地想做一番事业，建立新的技术。我们并不是在做生意；没有人申请专利。我们这样做，是因为这是一件令人兴奋的事，是一个艰难的项目，很有意思。如果我开发出了你能使用的东西，这就能给我满足感。就是这样。基本上，我认识那时互联网上所有的人。我们有一本小册子，自从有了电子邮件后，上面

有所有人的电子邮箱，所以我们知道怎样联系到每一个人，他们表现都很好。文化是开放的，免费分享道德，好的网络礼仪。这种文化是怎样产生的呢？有研究、有社区人员对教职工的感激，这就自然而然产生了，但 ARPA 大大加强了这种文化。ARPA 的资助哲学非常棒，他们来找你，说："看，我知道你是个很好的研究人员。这儿有一堆钱，在你擅长的领域做一些好的事情吧，我没法告诉你做什么事。记住我现在说的，我只想要你别让我们国家失望，我们知道你很棒，去做点事吧。"他拿钱给你，"做点大事，而不是小事，伟大的事。神话都可以。"我们称为高风险、高回报。互联网就是一个例子。政府说："我们不会打扰你。做你想做的事吧。"所以他们来找我，说："这是钱。做你想做的事。"我该怎么做？我去找我的研究生，根据他们的要求，我们有如下事情要做。我们需要宿舍协议。这儿有很多钱，动手吧。我们会告诉你们怎么做。如果你愿意，可以来问我建议，但要自己开动脑筋。所以，我们的想法是：开放、自由、创造力和同志情谊。我们没有对使用施加任何限制，而负面影响是我们没有采取任何保护措施。我们用不着彼此设防。我们本应当进行一些设置的，因为 1988 年，第一例蠕虫病毒出现了。1994 年，出现了垃圾信息。互联网的黑暗面开始了。我们也本应当在早期设置一些特别的工具的，在我们需要时把它们调出来，但是没有。所以现在很难得到安全了，这是一个严重的问题。

BZ: Also we need that kind of culture to lurch, cultivate and more young scientists life and, you know, where you were young and when you were work for those young graduate students too. Right?
LK：It was golden year that in fact things came together so well good funding philosophy, hard problems, smart people, uh MIT was a particularly exciting place in the time. And by the way, the person that I worked for, I told you I have worked for the best faculty around. I identified him as Claude Shannon. I'm not sure if you know his name, you should look them up. There's a book that just got published last month called A Mind at Play. Claude Shannon. He since passed away. Brilliant man! He's one of the originators of the digital revolution. I can tell you a lot about him, but he was on my committee. Okay? And he had the big view. He was wonderful mathematician of a very good engineer. Great intuition, big ideas. He worked at Bell labs and he was a playful guy. He played unicycle, juggle, keep the balance on the ball. And it's very critical; he wouldn't give praise easily. And his mind was click, click just, but you can tell it was it.
钟布：我们也需要这种文化来培养更多的年轻科学家，当你年轻的时候，你也在为年轻的研究生工作，对吧？
LK：这是黄金年代。事实上，一切发展得非常好，好的资助思想、困难的问题、聪明的人们。MIT 那时是一个特别令人兴奋的地方。顺便说一句，我那时协助工作的人，我说过我为最好的老师工作过，他是克劳德·香农。我不知道你是否听过他的名字，你应该查查看。上个月刚刚出版了一本书，叫做《游戏中的心灵》。他已经去世了。真是个才华横溢的人！他是数字革命的发起者之一。我可以告诉你很多关于他的事，但他是我委员会的成员。他有着宏伟的观点，是一位非常优秀的数学工程师，有着伟大的直觉和伟大的想法。他在贝尔实验室工作，是一个爱开玩笑的人。他会玩独轮车，能玩杂耍，能在球上进行平稳。还有一点很重要：他不会轻易表扬人。他的思想很锐利，你能感觉出来。

(1:00:33)
BZ: Thank you so much for showing us this kind of holly place. I feel like the more admiration for your work here. Can we go back and to your office? You know what? We're also interested in your personal story, how you grow up, how do you grow to such a great scientist? You know that's definitely inspiring.
LK: Notice that comment at an old cover. This is the comment of those days. This is the raise for these original lights.
BZ: So later on that you can take more pictures, but I really want to show your personal um, narratives.
LK: We want to take this whole wall and make it a big touch panel with all kinds of exciting things. I couldn't convince my chairman, my chancellor, my mayor, my governor, that this was something they should be proud of. It took years and years.
BZ: I'd like to help you spread this message out to the whole world. See how it is. That's near-sighted.
LK: It is very exciting. Yeah, that's by the way, the department is moving to a new building in November. I'm not moving. Okay, I want to stay near this room, right? And I want to keep my big office. One of the reasons I need a big office is to have a lot of books. People don't have books anymore. I can't let go of my books on it. They are too special.
钟布：非常感谢你带我们参观这个神圣的地方。对你工作的地方，我更加敬佩了。现在我们能去你办公室吗？我们也对你个人的故事非常感兴趣，你是如何成长，如何成为这样伟大的一名科学家的？这对我们非常励志。
LK：注意这旧封面上的评论，这是那时写下的评论。
钟布：晚点你可以拍更多的照片，但我非常想看看你个人的故事。
LK：我们想把这整面墙做成一个巨大的触摸板，上面会有各种各样让人兴奋的东西。但我无法说服我的主席、我的校长、我的市长和我的州长，这本来会是一件令他们感到自豪的事。它花了很多年时间。
钟布：我想帮你把这个想法告诉全世界。看看它是怎样的，唉，真是目光短浅。
LK：这太令人兴奋了。对了，这个部门将在 11 月搬去新的大楼。我不搬，我想待在这间屋子里，想保留我的大办公室。我需要大办公室的原因之一是因为我有很多书。现在人们没什么书了。我不能就这么放弃我的书，它们都非常特别。

(1:03:22)
LK: Uh, oh, that's going to be a problem. That's a heat exchange. And it will make that kind of noise. Can you manage it? (I think so.) Just got back from uh, an overseas trip, two nights. Where did you cruise in the Baltic? God, a wonderful trip! I went to Russia. (Have you ever been to China?) Yes, sir. A couple of times in the Beijing, Shanghai. There I have a former student who works out of Hangzhou now. I'm in constant touch with him. (1:05:24) (You do a lot of exercising? You look so good.) I just came back. I gained some weight on this trip because it was cool. There's always too much food. (Every day one pound.) Not quite so, but close.
BZ: Alright, that's good. Also I will sit in front of you, okay? And I'll talk to you before I started, our flyer a very good what we call the orchestra the internet. And we

were rewarded occupancy, you know, starting from the beginning. And here's the company to sing for me actually on several apps. And also we have a small gift for you. Um, I mean um, um, and this is like a flower to, uh, the only thing I think in a little bit, like unusual is this guy. This is a US. not very nice, but you know they designed very nicely. This is a business card. That's right. This is a bookmark.
LK: Thank you so much. Yeah, we're gonna have a big celebration on the fiftieth anniversary.
BK: We were planning that too. You know, in Harris and supported by UNESCO.
LK: Oh, really? We should coordinate in some sense. Yeah, we have our communications people and do you have a card? I have your information from the internet. This is so nice of you. Thank you.
BZ: I do. You know, and this is his card. I'll give you mine.
LK: Okay, my cards are right over here.
BZ: Uh, but my content, you know, um, I also teach content samples. So my heart is a university great person, but um, all the addresses you here is in the States. Here at Penn state on here. So everything is in my university service, university park and Pennsylvania, Penn state.
LK: Very good. Excellent.
BZ: Well we have read your interview back in 1990 with the University of Minnesota about that. So we do a lot of homework.
LK: I see that, that's great. It's a wonderful project by the way. It's been done well. Today background here was his history as well as technology.
BZ: Right? And you know, in addition to that, I cannot help noticing your beautiful pictures here. (That's my wife.) It’s your wife.
LK: It was in Europe. She was, uh, during World War II, she was in hiding. And after World War II, she went to a displaced person camp before she came here. And that was a scouting group.
BZ: So we'll start and I’ll begin to say where we are, what the date is. And you know and then I’ll ask you to pronounce your name. And tell us and the year you were born and then your parents’ name. Uh, I know you attended Bronx high school. Well, I’ll start.
LK: When you ask a question, you want me to repeat the question or your voice will be heard?
BZ: Yeah, my voice will be heard. It’ll be fine. Today's August 4th, 2017. Well, at the linc professor name, um, Kleinrock. Kleinrock’s office. Very honored to see this is very spacious office on the campus of UCLA, particularly as, the third floor of Belta hall, just next to the holy place of the birth of the internet. So we are very honored to be here. Um, Professor Kleinrock. And could you tell me and your name and a little bit of the background of yourself?
LK: （在办公室准备接受采访）糟糕，这会是个问题。那是一台热交换器，它会时不时地制造那样的噪音，这样行不行？（应该没问题。）我刚从国外旅行回来，住了两晚。你去过波罗的海巡航吗？这是一次奇妙的行程！我去了俄罗斯。（你去过中国吗？）去过，去了几次北京、上海。我之前有个学生，他现在在杭州工作，我经常和他联系。（你锻炼得多吧？看上去气色很好。）我只是刚回来，

这次旅行回来我长胖了一点，天气很凉爽，吃得太好了。（每天长胖 1 磅。）没那么多，但已经接近了。
钟布：好的，我坐在你前面，可以吗？在开始之前我会告诉你。我们的录音设备很好，我们想把你说的一切记录下来，这五十年你的成长，从头开始。我们也为你准备了一份小礼物，它们是精心设计的。猜猜这是什么？这是一张名片，对，这是一枚书签。
LK：非常感谢。对于五十周年纪念，我们打算进行大型的庆祝。
钟布：我们也有这样的打算，联合国教科文组织也支持。
LK：真的吗？那我们可以在某些方面合作。我们有负责交流沟通的人，你有名片吗？我可以在网上查到你的信息。太好了，谢谢。
钟布：有的，这是他的名片，我的在这儿。
LK：我的名片就在那儿。
钟布：但我名片上的内容……我也在大学教书，所以名片上我的地址都是在美国，在宾州。上面全是我大学的内容，宾西法尼亚州的。
LK：很好。
钟布：我们读过 1990 年明尼苏达大学关于你的采访，我们还是做了许多准备才前来的。
LK：明白，挺好的。对了，这是个很好的项目，做得很不错。今天这儿的背景也是它的历史和技术。
钟布：好的。除了那之外，这儿你这些美丽的照片也吸引了我。（这是我妻子。）啊，是你妻子。
LK：这是在欧洲拍的，在二战期间，她四处躲藏。二战结束后，在她来美国之前，她到了流离失所者营地，那是一个童子军营地。
钟布：那我们准备开始，我先说时间和地点，然后我让你说出自己的名字，并告诉我们你出生于哪一年，你父母的名字。我知道你上的是布朗克斯中学。好的，我准备开始了。
LK：当你提出问题时，你需要我重复一遍问题，还是你的声音足够大，能听得清可以录上去？
钟布：我的声音能录上，没问题。今天是 2017 年 8 月 4 日，我们在克兰罗克教授的办公室。特别荣幸地来到 UCLA 校园，走进这间非常宽敞的办公室。特别是这在贝尔塔大厅的三楼，紧挨着互联网诞生那神圣之地。我们能来到这儿，感到非常荣幸。克兰罗克教授，能告诉我你的名字和关于你自己的一些背景吗？

(1:10:42)
LK: My name is Leonard Kleinrock. I was born in New York City in Manhattan June thirteen, 1934. I was raised in New York at a time when New York City was the largest city in the world. Very, very special place. Um, I was actually born in Harlem, not that I live there, but the hospital was in Harlem. I live in a place called Washington Heights, which is very near to the George Washington Bridge. I had a great education in New York city. Elementary school was terrific, a lot of smart kids, very competitive for exciting. New York City, as you know, is a tough place. So you learn to protect yourself in the streets, and we'll get to that later. But, uh, and as a kid, I did the usual things. I liked to play with the gadgets, read comic books, model airplanes, play games, etc. And while I was in elementary school, I was reading a

superman comic and in the middle of a comic in the centerfold was a description of how to build something called a crystal radio.

And I was reading then said this is interesting. I can build this thing. It'll cost me nothing. And I'll hear music tune in radio stations. Let's build it like fine. And what I needed was things I could find around the house in the street, things like an empty toilet paper roll, and which I had to wind some wire to make what's called an inductor. The wire I could find in the street, I needed basically a crystal. It's crystal radio. And you can make that out of your father's razor blade on a piece of pencil lead. And I needed an earphone. I didn't have one, but I know that the candy store down in the street had a telephone booth. And I knew you could unscrew the earphone. So I stole the earphone. And then it needed something called a variable capacitor. One of these things that would allow you to tune it. And I didn't have that. I know I couldn't find that in the street, but I knew a way to get one. I knew that downtown Manhattan was a street called Canal street, another one called Cortland street. All the electronics that it was coming out of World War II, um, just before lot of. So my mother took me on the subway down there. I walked up to the first store I could find, and I bang my fist on the table, said, "I need a variable capacitor." And the man behind the counter said, "What size?" It blew my cover. I had no idea. So I told him what I was wanted and fully knew exactly what I needed.

LK: 我叫伦纳德·克兰罗克，于 1934 年 6 月 13 日出生在纽约曼哈顿。我在纽约长大，当时纽约是世界上最大的城市，是一个非常特别的地方。我出生在哈莱姆区，不是我住的那儿，而是医院在哈莱姆。我住在一个叫华盛顿高地的地方，离乔治华盛顿大桥很近。在纽约，我接受了良好的教育。小学特别棒，有许多聪明的孩子，很有竞争力。你知道的，纽约是一个挺不容易的地方，你得学会在街上保护好自己，我后面会讲到。当我还是个孩子时，我做了一些很平常的事。我喜欢玩小玩意、看漫画书、做飞机模型、玩游戏等等。在我上小学时，我读了一本超人漫画书，书中间的插页漫画是关于如何制作晶体收音机的描述。

我读着，觉得很有意思，我也能建造这样的东西，它又不会花我一分钱。我可以在电台里听音乐，那就照着它建吧。我需要的东西可以在街上的房子里找到，像空的卫生纸卷，可以在它上面绕一些电线来制作一个感应器。我能在街上找到电线；但我还需要一块晶体。这是晶体收音机，可以用父亲的刀片从铅笔芯上弄到晶体。我还需要一个耳机。我没有这个，但我知道街头的糖果店边有一个电话亭，你可以把耳机拆下来。所以我偷了那个耳机。然后它还需要一个可变电容器，用它来调频。我没有那个，我知道在街上找不到它，但我知道怎么找。我知道曼哈顿市中心有一条街叫运河街，还有一条叫科特兰街，那儿可以找到二战之后所有的电子设备，会有很多。所以我妈妈带我坐着地铁，一路到了那儿。我走进找到的第一家店，一拳砸在桌子上，说："我需要一个可变电容器。"柜台后面那个售货员问："什么尺寸的？"我一下就露馅了，完全不知道。因此我告诉他我需要什么，而他完全知道我需要什么。

He sold it to me for a nickel five cents. I came home and I put these things together. And I could certainly hear music. And this was fascinating. I had no idea how it worked. I said, I wanna find out what makes this work. And I'm still trying to find out. You know, electromagnetic is a mysterious world. We know the mathematics. We know the electronics electricity, but it's still a wonderful mystery. So I very much enjoyed making the… (How old were you at that time?) I was probably six or seven years old. Um, it was uh, so challenging to do this. You know, I like to build little things. And once I built that, I didn't realize it, but I was hooked. I was now destined to become an electrical, but I wasn't. It wasn't in my mind yet. And so when I was in high school, then I tested for what I was accepted at Bronx high school of science, which is a very special school in New York, best high school in the country, again with really smart colleagues, really wonderful projects. I had a wonderful time there. In fact, just two days ago when I got home from my trip, I received a letter from Bronx science. And they want to put me into the hall of fame among very few students and they are going to do that. So I studied radio electronics, among other things at Bronx science and that summer between high school and college, I took the job as a lifeguard, the end of the period I was on the swimming team in high school.

他以五美分的价格把它卖给了我。我回到家，把这些东西拼在一起，真的就能听到音乐了，这真是不可思议，我不知道它是怎样工作的。我说，我想知道是什么让它工作的。我现在还在努力地寻找答案。电磁是一个神秘的世界。我们了解数学，我们了解电子电气，但电磁仍然是一个奇妙的迷团。所以我非常喜欢做……（你那时多大了？）大概六七岁吧。这么做很有挑战性。我喜欢弄一些小东西。我在弄这些东西时，并没有意识到，但我被它迷住了。我注定要成为一名电气工程师，但那时我不是。我当时还没有想过。所以当我在高中时，我通过了测试，被布朗克斯科技高中录取了，它是纽约一所非常特别的学校，也是全国最好的高中，同事很聪明，项目很棒。我在那儿过得非常开心。事实上，就在两天前，当我旅游回来到家时，收到了一封布朗克斯科技高中的信。他们想要把我列入他们的名人堂，很少有学生能获得这份荣誉，他们打算这样做。我在布朗克斯科技高中学习了无线电电子和其他知识。在高中毕业升入大学前的暑假，我担任了救生员，这是我在高中游泳队的最后一段时间。

I was supposed to go to city college, CCNY. Now I really wanted to go out of town. So what I did toward the end of high school, I wrote to every chamber of commerce in every state in the country. And I ask what kind of scholarship to there, because I couldn't afford the money. And a number of them granted me some. But there wasn't enough, because tuition. Yes. But then there was some travel and women board. And even if I get all of that paid, I had to put money into the house. I had to earn money to help support the family. My father had become quite ill when he was in his early forties, so we had to stop—we ran a grocery store—he had to give it up. By the way, my parents weren’t rich. They both came from Austria. My mother came over when she was four years old, and my father came over after the First World War when he was 16 years old. (So your mom is also help with the grocery store?) She did some when my father began to get ill, she helps him. Otherwise she was a secretary before that. Interesting. My father got ill, couldn't work anymore. Need some money. So my mother, she was a very good typist. So she took in the work of typing addresses on envelopes. But she earned five dollars for a thousand. It’s hard work, but I saw her typing very quickly. So I taught myself to type. It was just fascinating. So I know how to type from very early. But we were not rich. We were quite poor. And so much so that.

我应该去纽约市立学院，但我真的想离开纽约。所以在高中结束前，我给美国每一个州的商会都写了信，问他们能提供什么种类的奖学金，因为我付不起学费。有不少给我提供了部分奖学金，但不够，因为学费很贵，还有一些出行的费用和住宿费。即使我能把这一切都付了，还得给家里钱；我得挣钱养家。我父亲在他四十出头时得了重病，本来我们开了一间杂货店，也不得不停止营业了，他不得不放弃店子。另外，我父母都没什么钱，他们都来自奥地利。我的母亲在 4 岁时来到了美国，我父亲 16 岁时，在一战之后来的这儿。（你母亲也帮忙打理杂货店？）在我父亲刚生病时，她在店里帮忙；在此之前她是一名秘书。我父亲生病了，没法再工作，又需要钱，所以我母亲，她是一名打字好手，就接了活，在信封上打印地址。但她打一千个才能挣 5 美金。这工作挺不容易，但我看见她打字速度非常快，于是也自学了打字，这挺有意思的。所以我很小的时候就知道应该如何打字。但我们都不富裕，其实是相当穷。这就是那时的情况。

CCNY, the city college of New York was the only place I could attend with no tuition and there’s been no room to board because I can live at home and I was ready to enter the day session like for electrical engineering students. But it turned out that that wasn't enough. I had to bring money in. So I had to go to night school. And I worked all day as a technician and industrial electronics form and I learned an enormous amount of. It took me five and half years in summer session. It took a three quarter load and I learned a great deal working. And you think about who goes to night session for electrical engineering degree, not too many people, either crazies or dropouts, or very dedicated poor students or GIs coming home from world war two, the GI bill and would rather interesting mix of classmates. So you learn things about life and what the real world is like. And at work I could learn the real use of electronics instead of simply the theoretical, because I was always very physical as well as theoretical. So for example, our professors at night, they themselves were working during the days engineers so they could bring all the knowledge they had about practical engineering as well as theoretical. I remember very well. One day my professor came in and we saw in a very small items and see this. That's a transistor. They were just coming out. And he said they have better thermometers than they are amplifies because they're very sensitive to heat variations, which is not what you want. And he showed us how to correct for that, putting additional circuitry around it. If that were a day session, they never would have said that said here's a transistor. Here is how it behaves. Go design. So the practical as well as the theoretical is a wonderful mix.

纽约市立学院（CCNY）是我唯一可以不用交学费就去上的大学，而且不用交住宿费，因为我可以住在家里。我准备好了，像电气工程专业的学生一样去上日校，但事实证明这还不行，我必须挣钱，所以不得不去上夜校。白天，我作为技术员，负责工业电子这一块，忙碌一整天，也学到了很多。我花了五年半时间在暑假学习，四分之三的时间在工作，也学到了很多和工作相关的。你会想，有谁会去上电气工程专业的夜校？没有多少人，要么就是疯子，要么就是辍学者，要么是非常认真的穷学生或是来自二战的退伍军人，他们有法案；我有许多有趣的同班同学，所以能了解生活和现实世界。在工作中，我能学到电子学的真正用

途，而不是简单的理论，因为我一直都很注意实际和理论的。举个例子，我们夜校的教授，他们自己在白天时也是工程师，所以他们能把所有关于实际工程和理论的知识带入课堂。我记得很清楚，有一天，我的教授走进教室，给我们看一个非常小的东西。那是一个晶体管，刚刚做出来的。他说用它当温度计的效果比扩音器要好，因为它们对热量的变化非常敏感，这不是他们想要的。他也向我们展示了要如何修正这个问题，那就是在它周围添加额外的电路。如果这是在日校，他们是绝对不会那么说的，他们就会说，这是一个晶体管，它有什么功能，去设计吧。所以实践和理论在夜校很好地结合在一起。

I learned a lot on TV session. (So you go to both day session and night?) No, only night session. I need work forty hours a week, (That's full time) didn't sleep much. In fact, it was difficult then I felt highly constrained and so late at night CCNY doesn't have fraternities or sororities. They have something called house plan. House plan was a building. Well, you could join clubs, be a bunch of guys in, let's call a house plan. I meant the group. And I was in a group called dean house. And there were women's groups also. And so you have dances for them. And I had to go there eleven o'clock at night after class until about midnight. And then I take the bus home. It doesn't have to be worked by 8am next morning. (So when do you study?) Well, I studied on the subway. What I would do is interesting. I would take an eight half by eleven piece of paper, fold it this way, and I fold it once more. And now I had eight sides, right? The formulas, the equations, and all of that. And on the subway I studied like this, going down and going back very crowded. It didn't have any room, did a lot of my study now and I did it very well. Um, I graduate first of my class day and evening. And I was the class president.

我在电视上学到了很多知识。（你是日校和夜校都上吗？）不，只上夜校，我一周需要工作四十个小时，（那是全职上班了）睡眠不足。事实上，那时相当困难，我压力很大，经常深夜还不能睡。CCNY 没有兄弟会或姐妹会，他们有房屋计划。房屋计划是一栋建筑。你可以加入俱乐部，和一群人在一起，就是家庭计划，是指一个组织，我加入的团体叫 Dean house。也有女性团体，大家可以跳舞。我晚上 11 点下课后去那儿，一直待到午夜，然后乘公交回家。我第二天早上 8 点才上班。（那你什么时候学习呢？）我在地铁上学习，学的过程很有意思。我会拿一张 8.5*11 英寸的纸，这样折一下，再折一次，现在这张纸有 8 条边了，对吧？公式、方程等等都可以写在上面。在地铁上，我就这样学习，上下班都很拥挤，没什么空间。但我这样学到了很多，而且学得很好。我以第一的成绩毕业，包括日校和夜校总排名，而且还是班长。

（1:20:53）
BZ: So what's the typical day look like, you know those days that you are attending college.
LK: Wake up at six thirty, get on the subway, be at work by little before 8 am. Work until five. Take the subway up to CCNY; it starts classes at six. Finish typically depends on the day like eleven, spent some time at house plan, take the bus home, get home a little bit, twelve thirty or one, try to get some sleep, get up next morning, start again. But uh, so it was a cramp life in undergraduate school, I get married, I was

earning money and I could pay for myself, and I needed to get out of that tight environment. So it was a good move, not too many people getting married that young. I was twenty years old. And then I put my wife to college. So toward the end of my bachelor's degree, I learned that someone from MIT was coming by to talk about a great fellowship scholarship.

And it was done out of MIT Lincoln laboratory. It was called something called a staff associate program. And they said, this gentleman is coming by at four o'clock on a Thursday and coming lessons. I took off work early that day. I made it up the next day I listen to this wonderful program. They send you to MIT, you get a job as a research assistant. They pay you. You'd work at Lincoln lab in the summers, doing research, get paid full time. There was even one semester when you got paid full time as if you were working there in the third semester, the fourth semester program. At the end of the third semester, you supposed to have finished your master's thesis. And fourth semester you spend in the Lincoln laboratory, which is twenty miles away from MIT and commute in MIT for the one or two courses you had left. That's exactly what I did. And my son was born right there. (At the end of the master degree.) That's right. Well, except for the commute. And that's what my professor said, “You have to go on for a PhD.” And I tell you I would only do that if I could work on something full of impact.

So anyway, this man came to describe this program. And he said, “If you want an application, see the professor in the back of the room when I finish lecture.” So at the end, I went to this professor and I said I'd like an application for this staff associate program. And he said, “Well, I don't recognize you. You are like your Virginia, I don't know. He was a professor. I don't recognize you.” I said, “Well, I go to evening session.” He said, “Evening session. Get out of here. You can't have an application. That's what you kidding.” So I wrote a letter to MIT and I got the application. And I was the only one accepted. That was a great program; there was a wonderful environment. And uh one of the first things I started, so I did my master's thesis, what became a paper some thin film memory, photoelectric and when I was looking around to work for this great professor Claude Shannon. The first thing he had me doing is working on a chess playing program. He was interested in many things. He wanted a machine that could play chess. So I worked on that for a while. Please show you an example of how smart it was. He handed me a book by someone named Fred Ryan who wrote most of the chess books. The book was called <u>A Thousand and One Billion Chess Sacrifices in Positions</u>. Every page in the book was a chest situation partway through the game. And the book said, “Black has brilliant secrets find it. Next page, “White has brilliant secrets finding.” But it's very hard to do. It was okay, chess play, but not, it's not my profession. Shannon put in the back of the book of the answers, look in the back of the book and find out, for example, what is the most common move, the first move of a brilliant sequence. What's the most common move? What's the second most common? What's the most common second move? And categorize them and build them into the program. By the way, you might want learning. You know. So it was a fine machine learning of putting the rules in to begin. The most common first move of a brilliant sequence is check. Make sense?

You nail them, they can't do much. Now you can see what's going. So, uh, Shannon was, he was very practical, and we wanted to play the middle game, not the beginning nor the end; the middle. We work with another professor, by the way, John McCarthy. You may not know his name, but John McCarthy and Marvin Minsky are the two original artificial intelligence… McCarthy was working on generating legal moves. McCarthy and his student would show us what you can do. It was up to Shannon to figure out what you should do. And this was the beginning the chess playing program. But this is not what I wanted to research on. I was looking around and I looked at my classmates and what were they working on? Well, I haven't described Shannon to what he created something called the information theory, and there's a whole book about him, twenty books. And he was supervising some students who working on extensions of that work. Most of my classmates were doing that either with Shannon or someone else. And I realized that the problems they were working on, were really very hard problems. And in my mind, not a great significance, a little step a little step. And that's not what I signed up for. And that's when I looked around for computers, I said they need to talk to each other. This is an area, but nobody's looking at. If I can solve, it will have impact. It’s a challenge. I had an approach. I saw what to do. And it's easy to get good result, because nobody's picked up the easy results yet. So it was perfect for me. And so that's what I did at MIT.

钟布：你上大学那些日子，通常一天是什么样的？
LK：六点半起床，上地铁，8 点前到，开始上班，一直上到下午 5 点。坐地铁去 CCNY，6 点开始上课。上完课的时间不定，有时 11 点下课，去房屋计划待一会儿，坐公交回家，到家 12 点半或 1 点，努力睡一会儿，第二天早上起来，重复开始。这种生活很紧张，在大学阶段，我结了婚，我在挣钱，可以养活自己；我需要摆脱那种紧张的环境。这是很好的举动，没有多少人那么年轻就结婚了，那时我 20 岁。然后我让妻子也上了大学。当我快获得学士学位时，我知道 MIT 有人要来谈一项很棒的奖学金，它是 MIT 的林肯实验室运行的，叫员工助理项目。他们说，这位先生周四下午四点过来，来课堂上。那天我很早就下班了，第二天再补上。我听了这个精彩的项目。他们送你去 MIT，你得到一份研究助理员的工作。他们会付钱给你。你夏天在林肯实验室上班，做研究，拿全职收入。第三个学期还是第四个学期，你在那儿工作，能拿全职报酬。第三学期结束时，你应当已经完成了硕士论文。第四学期你在林肯实验室待着，那儿离 MIT 有 20 英里。你通勤前往 MIT，完成剩下的一两门课程。这就是我做的。我儿子出生在那儿。（在拿到硕士学位之前？）对，除了没有通勤以外。我的教授是这么说的：“你得继续读博士啊。”我说除非我能研究一些很有影响力的课题，我才会读博。

总之，这个人来描述项目，他说：“如果你想要申请表，在我讲座结束时，去教室后面找那位教授。”最后，我去找这位教授，说我想申请这个员工助理项目。他说：“我不认识你。你是谁？我不认识。”我说：“我上的是夜校。”他说：“夜校。离开这儿，你不能申请。你是在开玩笑吗？”所以我给 MIT 写了一封信，获得了申请表。我是唯一一个被录取的。这是一个伟大的项目，环境特别好。我在那儿做的第一件事是写我的硕士论文，后来成为了一篇论文，和光电有关。我那时为这位伟大的教授克劳德·香农工作。他让我做的第一件事就是编一个象棋程序。他对许多事情都感兴趣，想要一台能下象棋的机器。所以我研究

了一段时间，让你看看它有多聪明。他递给我一本书，是弗雷德 瑞安写的，A Thousand and One Billion Chess Sacrifices in Positions，这本书里的每一页都是在游戏中出现的棋局。这本书说："黑色有绝妙的秘密，找到它。"下一页写着："白色有绝妙的秘密，找到它。"但这很难做到。象棋，还好，但这不是我的职业。香农把答案放在这本书后面，看看书后，找出，比如，最常见的棋招是什么，精彩的一盘棋的第一招。最常见的棋招是什么？第二常见的棋招是什么？最常见的第二招是什么？把它们分类并构建到程序中去。顺便说一下，你可能想学习。这是一台很好的机器，它把规则引入其中了。精彩棋盘中最常见的第一招就是将军。这有意义吧？你钉住他们，他们就无能为力了。现在你能明白怎么回事了。香农很实际，我们想在一盘棋的中间使用它，不是在一开始，也不是快结束时，是在中间。我们和另一名教授，约翰 麦卡锡合作。你可能不知道他的名字，但约翰 麦卡锡和马文 明斯基是最早的两位人工智能……麦卡锡致力于推动法律行动，麦卡锡和他的学生会告诉我们哪些事能做，而香农来告诉你你应该做什么。这就是象棋程序的开始，但这不是我想要研究的东西。我四处打量，看看我的同学他们在干什么。我还没有讲过香农，他创造了被称为信息理论的东西。有一整套书都是关于他的，20 本。他在指导一些负责扩展那个项目的学生。我的大部分同学，要么和香农一起，要么和别人一起。我意识到他们正在解决的问题是非常困难的。在我心里，它没有多大的意义，而是一小步一小步的。这不是我想参与的。在我环顾看到电脑时，我说它们需要彼此交谈。这个领域，没有人关注。如果我能解决，它就会产生影响。它是挑战，但我有办法，我知道该怎么做。要得到好的结果很容易，因为还没有人得到过轻松的结果。这对我来说很完美，这就是我在MIT 所做的。

(1:27:15)
BZ: That's very amazing. Many of us you interact with are wise, have a lot of wisdom, experience there. And you seem in those kind of young age identify where I could make best use of my wisdom. Yeah, it's not like a chess game. This may be still interesting, challenge your brain, pick your brain, but you want it to do something significant, have an impact. What I mean is the impact maybe social impact and affect…
LK: The point is I was going to spend perhaps four years; I didn't want to waste my time. I can be doing research as a mass system. I never would have been able to do the kinds of things I do now. But it was and it was a golden era at MIT. The faculty were amazing. My classmates were amazing people, people like Larry Roberts. Exactly. We had officers were graduates to his desk. Next to me was a student. He was working on one of the first mechanical hands, mechanical hand with visual senses. So it could pick up objects and avoid bumping into them. Interesting story. He finished, he worked on the Shannon, he finished. Desk goes empty, the phone rings. I pick it up. It's the Boston Globe, the newspaper. And they say, "I'd like to talk to the man who, you know, build the mechanical man." I said, "He's left, he's not here anymore, but it's not a mechanical man." I said, "It's a mechanical hand." And they said, "What's the difference?" They wanted a big story. That's the press for you. But that's the way I got into it.

BZ: So you when you look around, there's not lot of things I guess, and you look around, but finally a new thinking networking put computers together will be very important. How the process look like and what other things will be available there in those years?
LK: So it's not that I said I want to look at the problem of computers talking to each other. I realized they needed that. Now how to make it happen? And all we had in those days were telephone networks and some telegraph networks, but nothing that could handle different kinds of computers with different kinds of languages and do it efficiently. And the important, the key idea there was the... In those days, communications were very expensive. And the switching was also expensive. So when the telephone network began, they decided to waste communications wasn't as expensive as the switching. Remember, keyboard operated. That was expensive. So once they set up a connection, they kept it up even as being wasted. And with voice, you only lose about one third, but with data, you can't assign a permanent connection for the duration of a day to call.

So the idea was to allow all those links to be used by other people when I'm not using it in my conversation with some of the machine, so that it was not to assign a link for permanent conversations, but dynamically, it's called resource allocation or resource sharing. Now, it turns out that that basic idea was already in the air before this networking came about. We had time-shared computers. Now what's the time-shared computer? It is a machine that's very expensive. Personal computers have bad example. Think of a big IBM mainframe. For a single person to sit at a keyboard and use that machine, it was very inefficient. Because what I'm trying to write a program at the council with the multi-million dollar machine. I tried program and I failed. I say, why is it not working? Spending most of the time scratching my head instead of using the machine. And as a user, the user love that the very first machines were personal computers, those big machines. But when they got expensive, they threw the user out of the computer room. This is being used too inefficiently. And they said, "If you want to use it, present the deck of cards. It's called batch processing. You present the deck and they run one after the other until you submit a job, Ronnie, two days later, you come back to get a pile of printed output. Trouble is you seldom got a pile of ended up. You got one page. The page said, "Syntax error, job aborted." I'm not even tell you since you forgot the semicolon on line forty two, so you submit it again two days later, another syntax error.

Now, the people who own those machines loved it. They were running jobs all the time, making money, and the user hated it was before the user loved the personal machine on the computer on the side. Well, I'm giving a lot of history here. Basically the users revolted. And so they allow the user back into the computer room at the end of the terminal. And basically said, you can submit a job and get a response back immediately. But when you're quiet, someone else gets in, share the processor, dynamic resource sharing. You don't own it. You only get to use it when you need it. So I said that's exactly the idea we need for communications. You don't get to keep the communications link. You only get to use it when it's ready to be used. And that's where the notion of a queue is so important. A queue, people waiting a line to use a server. It’s a perfect resource sharing the device. Why? The server is not waiting for somebody else who's not there yet. Whoever is in the head of the line gets to use it. The work is there, you do it. It’s always working with his work to be done instead of waiting in an idle case. So I apply that, I develop the mathematics. And this in fact is the book that came out of my dissertation. It was published in nineteen sixty four by McGraw-Hill.

钟布：真是神奇啊。你接触的很多人都很聪明，有许多智慧和经验。而你似乎在年轻时就意识到你可以充分利用好自己的智慧。是的，这不像下一盘象棋。挑战你的大脑、让它进行选择，可能也很有意思，但你想做一番大事，有影响的事。我说的影响是指社会影响……

LK：重点是，我也许要花上四年时间；我不想浪费时间。我可以在大的体系里做研究，我从来都无法做现在自己做的这种事。但它的确如此，它是 MIT 的黄金时代。教职工特别好，我的同学都是了不起的人，像拉里·罗伯茨那样的人。正是如此。我们办公室里都是大学生，坐我旁边的一个学生，他是最早研究机械手的人之一，具有视觉感官的机械手。它能拾起物体而不会撞上它们。很有趣的故事。他完成了，他和香农一起工作，做完了，就走了。桌上空空的，电话响了。我去接电话，来电的是《波士顿环球报》，他们说：“我想和那个，你知道的，制造机械人的那人谈谈。”我说：“他离开了，他不在这儿了，但他不是制造的机械人，他制造的是机械手。”他们说：“有什么不同吗？”他们想要轰动的故事，这也是给你的压力，但我就是这么开始干了。

钟布：当你环顾四周，我猜并没有多少东西，但最终，你有了新的想法，用网络把电脑连在一起，这很重要。这个过程是怎样的呢？在那些年，还有其他什么可以用到的东西吗？

LK：并不是说我想研究计算机之间相互交谈的问题，是我意识到它们需要交谈。那怎样来实现呢？那时我们只有电话网络和电报网络，但没有任何东西可以处理使用不同语言的不同种类的计算机，并高效地进行操作。最关键的是……在那时，通信非常昂贵，转换成本也很高。所以当电话网络建立起来时，他们决定浪费通讯，因为通讯没有转换贵。记住，键盘操作，很昂贵。所以一旦他们建立了连接，即使时间被浪费了，仍然保持着连接。对语音来说，只损失了大约三分之一；但对于数据，你不能在一天时间内分配永久连接来通话。

所以我们的想法是，当我在和机器的对话中不使用这些链接时，允许其他人使用这些链接，这样它就不会为永久对话分配链接，而是动态地分配，这被称为资源分配或资源共享。现在，这个基本想法在网络出现之前就已经存在了。我们有共享计算机。什么是共享计算机？它是很昂贵的机器，个人电脑有不良先例。想想一台 IBM 大型机器。对于个人来说，坐在键盘前使用这台机器，效率非常低，因为我正试图用这台价值数百万美元的机器为理事会写一个程序。我尝试编程，但失败了。我问：“为什么它不工作呢？”大部分时间我都在挠头，而并非在使用机器。作为一名用户，他喜欢的第一批机器正是个人电脑，这些大的机器。但当它们变得昂贵起来后，就把用户扔出了机房。这样的使用太低效了。他们说：“如果你想使用，就拿出一叠卡。它就是批处理。你展示这叠卡，它们就会一个接一个地运行，直到你提交任务：“罗尼，两天后，你回来拿一堆打印出来的结果。”问题是最后你很少能拿到一堆结果，而只有一页纸，纸上写着：“语法错

误，任务中止。”我也不会告诉你，由于你忘记了 42 行上的分号，两天之后你再一次提交任务，结果又是语法错误。

现在，拥有这些机器的人很喜欢它。他们一直在运行任务、赚钱。用户讨厌它，因为之前用户喜欢机器旁边的个人电脑。这儿我聊了很多历史。基本上，用户是会反抗的，所以他们允许用户回到机房，坐在终端尽头。基本上，你可以提交任务，然后立刻得到回复。但当你没有动作时，其他人会进来，共享处理器，动态资源共享。你并没有它的所有权，只是在需要的时候才使用它。我说，这正是我们交流所需的想法。你并没有一直保持沟通链接，只是在它准备好时才使用它。这就是队列概念的重要性所在。人们排着队等着使用服务器。这是一个完美的资源共享设备。为什么呢？服务器并没有在等待那些还没有进来的其他人。无论是谁，排在队伍前列，就可以使用它。工作就在那儿，你来干吧。服务器总是有事情做，而不是在闲置状态下等待。我把它应用起来，发展了数学。这实际上是从我的论文中写成的一本书，在 1964 年由麦格劳—希尔公司出版。

BZ：So yeah, I heard this story. So, um, you're still assistant professor of...

LK：In 1964, I was. I came here in 1963. So it went out of print and Dover reprinted it. This went out of print and Dover reprinted it again. And that recently came out. Same stuff. (So this actual required out of mathematics training also.) Well, yeah, I learned a lot of the mathematics myself as an electrical engineer. You learn some great mathematics, but you don't study queuing theory. I needed to use queuing theory. So I wrote two books on queuing theory when I was here, volume one, volume two, this is all about the theory. And this is the first book about networking. It talks about the ARPANET experience and the tools, some of the tools from here expanded between the nineteen sixty two work and in nineteen seventy six work. And these uh, these books are now the classic works of queuing theory. And of course, there are many other books on queuing theory that have come out since.

BZ：Let's go back a little bit to the fathers of internet. We got amazed by that terms. Um, we really know and several versions about and who should be credit as fathers of internet. What's your opinion?

LK: My thought is so you can refer to some of the fathers it confront to other people as well who contributed vastly to the internet. The conclusion is the internet would have happened if none of us were born. The ideas when they were waiting to happen. In fact, the idea of an internet kind of system was predicted many years ago in different contexts. For example, I’m gonna quote you. The quote goes something like this, “It will be possible for a businessman in New York to communicate with his colleague in London using a device no larger than a watch immediately be able to send any text, picture, message, drawing anywhere in the world.” Now that man is talking about something that sounds like the internet. It’s immediate, it’s cheap. It’s easy. It’s global. You can send all kinds of media. That quote is from Nikola Tesla, 1908, more than a hundred years ago. He was talking about wireless communications. He didn't mention video because there was no video then. But the idea of such a capability was already present. And then we have people like H.G.Wells, we have for people like uh, the Glider. We have others like, um, uh, myself, you saw my vision and the number of others along. The ideas were waiting for technology to catch up and it would have happened even if none of us were around. So when you talk about the fathers of the internet, yes, four of us. Typically, I've listed as the fathers by various groups, but we were lucky. We were there at the right time. We saw the right things to do. And it was thousands of people contributing in the early days.

钟布：是的，我听过这段历史。所以，那时你还是副教授？
LK：1964 年，是的。我是 1963 年来这儿的。这本书脱销了，多佛进行了加印。这本也卖完了，又是多佛把它重印了，这是最近才出版的。同样的书。（所以这其实也需要数学训练？）是的，作为一名电气工程师，我自学了很多数学知识。你得学习一些伟大的数学，但没有学习队列理论。我需要使用队列理论。所在当我在这儿时，我写了两本关于队列理论的书，第一卷，第二卷，都是关于队列理论的。这是第一本和网络相关的书，它讲述了阿帕网的经历和工具。这儿用的一些工具在 1960 年和 1976 年之间得以扩展，这些书现在是队列理论的经典著作。当然，从那时起，还出版了许多其他关于队列理论的书。
钟布：我们回到互联网之父这个话题吧。对这个术语，我们很是惊讶。我们知道好几个版本，那谁应该被称为互联网之父呢？你有什么想法吗？
LK：我的想法是，那些对互联网做出巨大贡献的人，都可以被称之为互联网之父。 结论是：即使我们都没有存在，互联网也依然会出现。这一切已经做好了准备，随时都会发生。事实上，互联网这种系统的概念早在许多年前就在不同的环境中被预言了。例如，我要给你引用一段话，这段话是这么说的："纽约的一个商人可以用一台比手表还小的设备，与他在伦敦的同事进行交流，设备可以立即把任何文本、照片、信息及图画发送到世界任何地方。"这个人谈论的正是听起来像互联网之类的东西。它即时传送，经济便捷，全球通用。你可以发送各种各样的东西。这段话引自 1908 年的尼古拉 特斯拉，距今已经有一百多年了。他谈论的是无线通信，并没有提到视频，因为那时还没有视频。但这种能力的想法已经出现了。还有赫伯特 乔治 威尔斯，还有格莱德，还有其他一些人，像我自己，你明白我的愿景；还有许多其他人。这些想法都在等待着技术的进步，即使我们都不在，它也同样会发生。所以，当你在谈论互联网之父时，它是指我们四个人。通常情况下，不同群体都把我列入互联网之父，但我们很幸运。我们拥有正确的时机并获得了成功。我们知道什么是正确的做法。在最开始，有成千上万人为此做出了贡献。

(1:37:48)
BZ: Do you think that is an accidental event that all the fathers of internet come from MIT?
LK: No, they don't. Vint Cerf does not for example. He came out here actually, one of my graduate students. Bob Kahn and I both got our undergraduate electrical engineering degrees at CCNY, two of us. That's pretty impressive. But Larry got his training, his undergraduate training there. I got my graduate training at MIT. Kahn came here as professor for a short while, but a lot of the work was done at MIT. You're right. (Did everybody there work for internet?) Actually Lincoln lab is a very interesting case because Larry and I work for Lincoln lab. Bob did not, Vint did not, but Wesley Clark, the one who suggested the IMP worked in MIT, Fan Karl, the fellow BBN who ran the group there. He was at Lincoln lab when I was there. So Lincoln lab was a kind of hotbed of great ideas, and it was late at MIT.

BZ: Let me ask you something about Donald Davis, yes, Donald from UK. And some people said he was so unfortunate because he did not get funded, because you get wonderful ideas. So what's really?

LK: So here's the story. Donald Davies began to get interested in networks around nineteen sixty five, he began to talk about it that years after this work was done. And he was aware of this work, he talks about it. He was also aware of Paul Baron's work. Paul Baron is working just down the street of Ran Corporation on military problems. That's another source of this urban myth. But he was just trying to create a network which would in fact be robust against an attack. But he wasn't looking at any of the mathematics and the fundamental principles that came out of here. He was looking at the architecture. His first key paper came out in September 1962. My first baby came out in April 1962 when I talked about packet switching, but our work was independent, we were contemporary. Davis came later. He was aware of the work of Baron and myself, but he did convince the UK he was working at the national physical laboratory. He is telling to me. He convinced the UK to help allow him to build a one node network. The first switch even before our switch. But he couldn't get the UK to fund multiple nodes. And one node is not a network. If they had funded him, you'd be interviewing someone today with a British accent. But it is unfortunate. And he was greatly disappointed. In fact, it would be that. But his work was interesting, but it came a little later, but it was first to implement the switch.

BZ: Can you also talk a little bit about like a Paul Baron and his work. And he got some ideas, but not seems concrete enough to be the sort of a view from the fathers of the internet like it could have. So tell us a little bit more about Paul's work.

LK: So Paul was working on problems of reliability and vulnerability of networks. We talked about adding a lot of extra communication links. So he knocked out some, the others would remain. He was talking about performance of these things, the architecture. In September 1962, he began to talk about breaking messages up into packets. I already talked about that in April 1962. Work was independent, but he did more of the engineering architecture. Mine was more of the mathematical principles in the fundamentals observing things, like bigger is better. A larger network with more capacity and more throughput gives you much better response time. Queuing theorists didn't know that. Queuing theorists will say the following, "You have a waiting line and service, a grocery clerk. You can't make the clerk work any faster than one second per second." But in a network, you can make the communications link go faster, hundred bits per second, a thousand, ten thousand, hundred thousand bits per second. And the faster you make that, and the more throughput you handle, the lower the response time, the faster you get through on average. Queuing theorists didn't know that, but I could put that very easily, so bigger is better.

I also found out that, for example, single nodes are better rather than multiple nodes in one location. I found distributed systems. When I was thinking about networks in my work and working for Shannon. Shannon's work was based on the principle that systems get larger whatever they are. He was talking about networks, he was talking about coding sequences. As they get larger, they get more predictable and the fluctuations go away. I'll give you an example, and we'll get the Baron. The insurance companies know exactly how many people are going to die next year. They just don't know who, so they bet with everybody. They increase the rates a little bit. And they always win because nature, if you let nature operate long enough with it, probabilistic behavior, he behaves very deterministically. That's something called the law of large numbers, a large population of unpredictable events collectively behaves in a very predictable fashion. So Shannon took advantage of that. And I took advantage of that. I said if I'm gonna build the network, I'm going to study the behavior of large networks. The title of my thesis uh, was not quite this, but the proposal was called information flow in large communication networks.

So I realized a little communication. It was ten, twenty nodes. Nothing emerges. But in a large network, you'll see emerging behavior. (This reminds me and what we learn from statistics of theta.) Exactly. It's predictable. Yeah, you know, the law of large numbers tells, you know, the variance shrinks. So I said, I want to build a network. And how do you build a large network? You can't have one node controlling everything. It's vulnerable, it's too much traffic, it takes too long.

We distribute the control. So the idea of distributing control was in my dissertation, not because I wanted reliability, but because I wanted scalability. You get reliability as a consequence for free. You can chop pieces often. So continue this work. So as in getting back to Baron, I was interested in the finding those principles, large shared networks are better, distributed networks are better, and chopping messages in small pieces makes sense for a variety of reasons. Baron wasn't talking about those. He said from an engineering point of view, the network could look like this and had the idea of package, which in no question about it.

His work was parallel to mine, sort of like that. His was more engineering architecture. Mine was theoretical in principle based. So he went to AT&T also with his ideas and he got the same story, "It'll never work. We don't wanna do it." And he tried to get them to build a network. And they wouldn't. And he got discouraged. And he stopped working on networks and he began to work on other systems. He did talk with Larry a bit near the early days because Larry knows all about my work, we actually help. I wrote a simulation program. He wrote the compiler for the machine that TX 2 computer when I was using. So we overlap them. So the very early pioneers are myself and Baron in the early days. Then you get David's coming in. And then you get people like Roberts coming and then later Frank Hard and such like. Vint came in quite a bit later. Kahn was there with the BBN guys. Vint came in, working for me. Here is my software code. And they put together, he and Steve Crocker, my group was as follows: Haul is the PI, had a software cope. Steve Crocker was in charge. Under him was Vint, was Charlie Cline, was John Pastal at a hardware group and that staff and programs etc. Vint was involved with Crocker on the first host protocol. It was called NCP, the network control protocol, long before TCP. Then in 1973, Bob Kahn was now in charge of the computer group at ARPA. He recognized that this ARPANET was now getting other networks attached to it. He had a satellite network from Europe, the ALOHA network from Hawaii. And he anticipated every one that works. And in order to let NCP talk to each other, each network how to translate into the other networks, protocols. That works for three or four networks, but it grows it grows like N squared. So Bob recognized we need a comment protocol and then began to work with them to implement it because Vint in helping me the NCP so then TCP began to emerge around 1973, and by 1983 it was then required. And you have to use TCP/IP. There is also another related story here. TCP is a host's protocol. It tells you how to get data from one host to another. And it has ruled, for example, I send the message, you get an acknowledgment. If you don't get an acknowledgment, send it again. Inside the network, it gets chopped up. And if there's too much traffic, it begins to go slow. You slow down this rate and such like. And it forgets there is an error we transmit. You can stay out of order, put it back in order, fine, but Danny Cones, the fellow who return my razor was in those early one of the pioneers. He was interested in something called a network voice protocol. He wants to send voice, we call that VO, voiceover IPs, voice to the network. When TCP came out, it combined what we now call TCP/IP. TCP is the end to end protocol. IP is by hot protocol, very efficient. He recognized that he could not send voice through the network if TCP was running the show. Because if a packet gets there out of order, you wait until you get those that came before it. We get an error. If you transmit it, you wait for it. Voice can't wait. It's real time. If it gets the late, throw it away. It gets out of order, throw it away. It gets there wrong, throw it away and interpolate. So he argued with Bob and Vint to break TCP into two pieces, the IP part and the end part, so he could run what he called, not the voice protocol on top of IP without using TCP. We call that streaming media today.

钟布：所有的互联网之父都来自 MIT，你觉得这是巧合吗？
LK：不，并不是所有的都来自 MIT，像文顿·瑟夫就不是。其实他来自这儿，是我的一名研究生。鲍勃·卡恩和我都在 CCNY 获得了电气工程本科的学位，我俩都是。这让人印象挺深刻。但拉里在 MIT 进行了培训，他的本科就是在那儿读的。我在 MIT 受到了研究生培训，卡恩以教授的身份来过这儿很短一段；但很多工作都是在 MIT 完成的。你说对了。（那里的每个人都在为互联网工作吗？）事实上，林肯实验室是个很有意思的例子，因为拉里和我在林肯实验室工作。罗伯特没有，文顿没有，但威斯利 ·克拉克，就是那个提出 IMP 的家伙，在 MIT 工作。范 ·卡尔，BBN 在那儿管理团队的人，当我在那儿时，他也在林肯实验室。所以林肯实验室是伟大想法的温床，后来 MIT 也是。
钟布：我想问你一些关于唐纳德 戴维斯的事。唐纳德是英国人，有些人说他很不幸，因为他有很好的想法，但得不到资金。真实情况是怎样的？
LK：他的情况是这样的。唐纳德 戴维斯在 1965 年左右开始对网络产生兴趣，在这工作完成几年后，他开始谈论这一点。他知道到这项工作，也对它进行谈论。他也知道到保罗 巴伦的工作。保罗 巴伦就在这条街的一个公司研究军事问题，那是都市神话的另一种来源。但他只是在尝试建立一个强大的网络来抵御攻击，他并没有研究数学和基本原理；他在看建筑。他的第一篇重点论文发表于 1962 年 9 月，我的第一个孩子出生于 1962 年 4 月，当时我在谈论分组交换。但我们的工作是独立的，我们是同一时代的。戴维斯后来出现了，他知道巴伦和我的工作，但他确实说服了英国，那时他在国家物理实验室工作。他告诉我，他说服英国帮他建立一个单节点网络，这是第一个转换器，甚至比我们的还要早。但他无法让英国为多节点提供资金，而单节点不是网络。如果英国资助了他，你们今天

就会采访一个带有英国口音的人了。不幸的是，他非常失望；其实这真令人失望。但他的工作很有趣，就是来得晚了点，可它是第一个实现转换的。

钟布：你能谈谈保罗·巴伦和他的工作吗？他有一些想法，但似乎不够具体，那些观点不足以让他成为互联网之父。跟我们讲讲保罗的工作吧。

LK：保罗当时在研究网络的可靠性和脆弱性。我们讨论过增加很多额外的通信链接，他弄掉了一些，留下了一些。他讨论的是这些东西的性能，是建筑。在 1962 年 9 月，他开始讨论把消息拆分为数据包。我在 1962 年 4 月已经讨论过那个了。我们的工作都是独立的，但他更多地在做工程架构，而我的工作则是更倾向于用基本原理中的数学原理来观察事物，像“大就是好”。一个容量更大、吞吐量更大的网络可以提供短得多的响应时间。队列理论家并不知道这一点。队列理论家会说：“你有等待的队伍和服务，一名杂货店店员。你不可能让店员以比每一秒一人更快的速度提供服务。”但在网络中，你可以让通信链接更快，每秒 100 比特、1000 比特、一万比特、十万比特。你做的越快，处理的吞吐量越多，响应时间越短，平均速度就越快。队列理论家不知道这一点，但我可以很简单地说，大就是好。

我还发现，例如，在一个位置上，单节点比多节点更好。我发现了分布式系统。当我在工作时和我为香农工作时，我都在思考网络。香农的工作基于这样一个原则：无论是什么系统，它们都会越来越大。他说的是网络，说的是编码序列。当它们变大时，它们变得更容易预测，波动就会消失。我给你举个例子，然后就会谈到巴伦。保险公司确切地知道明年会有多少人死亡，他们只是不知道谁会死亡，所以他们和每个人打赌，把税率提高了一点。他们总能赢，因为自然规律。如果你让自然运行足够长的时间，这就是概率行为，它的行为非常具有决定性。这就是所谓的大数定律，大量不可预知的事件以一种非常可预测的方式集体发生。香农利用了这一点，我也利用了这一点。我说，如果我要建立网络，就要研究大网络行为。我论文的题目并不是这个，但这个提案被称为大型通信网络中的信息流。

所以我建立了一些小通讯，有十个、二十个节点，但没出现任何东西。可在一个大型的网络中，你会看见正在出现的行为。（这让我想起了我们从统计学中学到的东西。）完全正确。它是可预测的。大数定律告诉我们，方差减小了。我说我想建立一个网络。你怎样建立一个大型网络呢？你不能让一个节点控制所有的东西。它太脆弱了，通信量太大，需要太长时间。

我们对控制进行分配，分布式控制的想法出现在我的论文中，不是因为我想要可靠性，而是因为我想要可扩展性，结果就免费得到了可靠性，而且可以经常把消息分解，然后继续这项工作。回到巴伦的话题上，我对发现这些原则很感兴趣，大型共享网络更好，分布式网络更好。而且由于各种原因，把消息分割成小块很有意义。巴伦没有讨论这些。他说，从工程的角度来看，网络可以是这样的，并有数据包的想法，这是毫无疑问的。

他的工作和我的差不多。他更倾向于工程建筑，我的则是以原则为基础的理论。他带着他的想法也去了 AT&T，遭遇了同样的故事：“它绝不可能成功。我们不会做的。”他努力地想让他们建立一个网络，但他们不会那么做。他受到了打击，很失望，不再研究网络，开始研究其他系统。在刚开始时，他的确和拉里谈过，因为拉里知道我所有的工作；我们确实帮了点忙。我写了一个模拟程序，他为我使用的 TX2 电脑编写编译器。我们把工作重叠起来。早期的先驱就是我和巴伦，然后是大卫，然后像罗伯茨他们，后来是弗兰克·哈德之类的人。文顿

过了很久才出现，卡恩和 BBN 的人也来了。文顿出现时，他为我工作。这是我的软件代码，他们把他和史蒂夫·克罗克放在一起。我的团队组成是这样：豪尔是 PI，负责软件控制器。史蒂夫·克罗克是负责人。在他下面是文顿、查理·克莱因；约翰·帕斯塔尔在硬件小组，有工作人员和程序等等。文顿和克罗克参与了第一个主机协议，它被称为 NCP，即网络控制协议，比 TCP 早很多。1973 年，鲍勃·卡恩负责 ARPA 的计算机小组。他意识到，这个阿帕网正在和其他网络相连接：从欧洲来的卫星网络，从夏威夷来的阿罗哈网络。他预测了每一个可运行的网络。为了让 NCP 互相沟通，每个网络要如何转换成其他网络，协议。这适用于三或四种网络，但它不断增长，就像 N 的平方一样。鲍勃意识到我们需要一份常见的协议，然后开始与他们合作来实施这份协议，因为文顿帮助我实现了 NCP，所以 TCP 在 1973 年开始出现，到了 1983 年，它成为了必需。你必须使用 TCP/IP。还有一个相关的故事。TCP 是主机协议，它告诉你如何从一台主机获取数据并发送到另一台主机。它规定，例如，我发送信息，你会得到确认。如果你没有得到确认，那就再发一次。在网络中，它被分解成小块。如果信息太拥挤，就会变慢，你就会降低速率。它会忘记我们传输中有错误。你可以保持秩序，把它按秩序放回去，没问题。但是丹尼·科内斯，那个归还我剃须刀的人，是早期的先驱者之一。他对一种叫做网络语音协议的东西感兴趣。他想发送声音，我们称为 VO，从网络传送声音。当 TCP 出现时，它结合了我们现在所说的 TCP/IP。TCP 是端到端协议。IP 是通过热协议，非常高效。他意识到，如果 TCP 正在运行这个节目，他就不能通过网络发送语音。因为如果一个包被打乱了，你就只能等着在它之前传送的东西。我们会碰到错误。如果你传输它，就得等待。语音无法等待，它是实时的。如果迟了，它就被扔掉了。如果秩序乱了，它也被扔掉了。如果传送错了，它也被扔掉了。所以他和鲍勃及文顿争论，要把 TCP 分成两个部分，IP 部分和终端部分，这样他就可以运行他所要的，而不是没有 TCP 的 IP 上的语音协议。我们今天称之为流媒体。

It enables streaming media, which is one of the dominant uses of the internet today. And it was a big fight, as I understand, to get TCP problem into two pieces. A TCP does have this, well behavior where you get more throughput than you drop it in half. I don't know if you're familiar with the protocol. It’s very bursting in burpee. And the person who put in some control, congestion control functions was gonna invent Jacobsen. He put in what we now know is the TCP equation one.

Now, in nineteen seventy nine, I published a paper seventy eight, and then another paper, seventy nine. And I explained that the way to get efficient performance is not to let the queues build up, but to keep the minimal. The theory is this, here is queue and the server. Suppose you want to minimize the time it takes to get through here and still keep the server very busy. If you could control how you put people in, what would you do? You put one person in and let him get served when he leaves, put another one in. Don't put people in the queue because that's slowing things down. And the engineering concept there is keep the pipe just full. If you have many cups, keep one in each cup. Don't flood it with a lot of other stuff that gets in the way in buffers and what's called buffer block. I published that. Nothing happened to it. Last year, Brian Jacobsen looked at the paper again, said, that's the way to do it. And he's working for Google now. And one of their data centers just published a paper saying this, just keep the pipe wasn’t the way to do it. And they're getting rid of this kind of behavior now. So I mentioned TCP, this is going to replace TCP, I believe.

它支持流媒体，这是当今互联网的主要用途之一。正如我理解的，把 TCP 问题分成两部分，是一场巨大的斗争。TCP 确实有这个功能，好的地方在于你会得到比你一分为二投入的更多的吞吐量。我不知道你是否熟悉这个协议。实施控制、拥堵控制功能的人……他提出了我们现在知道的 TCP 方程式一。

在 1979 年，我发表了一篇论文——是 1978 年，1979 年发表了另一篇。我解释说，获得高效性能的方法是不让队列累积起来，而是保持最小值。理论是这样的：这是队列和服务器。假设你能把通过这儿的时间减至最少，并仍然让服务器非常繁忙。如果你能控制如何放人进去，你会怎么做？你让一个人进去，在他离开前获得服务，再让另一个人进去。不要让人们排队，因为那样会减慢事情的发展。这儿的工程概念是保持通道满员。如果你有很多杯子，就在每个杯子里放入一个。不要用其他很多东西把它塞满，那些东西会阻碍缓冲，也就是所谓的缓冲块。我发表了那篇论文，但没有任何反应。去年，布莱恩 雅各布森又看到了那篇论文，他说，这就是解决问题的办法。他现在在谷歌工作，他们的一个数据中心刚刚发表了一篇论文说到这个，说保持通道满员不是正确的解决方法，他们正在摆脱这种行为。我提到了 TCP；我相信它会取代 TCP。

(1:52:37)

BZ: That's where I want to go to you to ask you about this. So before I came here, I think on your contribution is a very radical, you know, set up a ceramic framework for the networking. By proposing this kind of wonderful queuing theory and also help the packet-switching, am I right?

LK: Yes, you are. The introduction of queuing theory as the tool and the way to think about the system was what I basically recitation. And I had never studied queuing theory by the way. I learn it on my own. And then I wrote these books. But because it's the right metric, it allows for the probabilistic aspect of it, what you see and unpredictable traffic and even unpredictable network or reliability. Now lines come and go. And then I needed to take that theory and suggest a way to build a network around it. And that's where the packet-switch came in. And all the performance evaluation is a lot of performance. I don't know if you look at this book, a lot of genetic as well, but I’ve got all the mathematics here. And I’ve got the top logical structure here. And I’ve got the simulation. Here we go. A large number of simulations, and here, then many many simulations here, for different architectures, random routing, distributed routing. Here, I’m showing you the theoretical results and the simulation results, and they line up so well, this goes with the final good. And I did a lot of simulations, because I had to make some assumptions in my theory. Are those assumptions good? You can build a network. Just too expensive, was simulated. That's what is TX 2 for. A lot of that came out of the law of large numbers results. There's certain things you can assume network anyway. So the idea of the building a network, the fact that nobody wanted to build a network after I was done was very disappointing. It took years before operating. Yes we want. And that was a big turning point.

BZ: So at the moment and when you try to connect those computers from those lots of even among all so many universities, campuses, do you envision do for, some day the internet will be used by everybody?
LK: No, I missed that. (Like nineteen o eight. Had someone…) I didn't see that use. I thought as I said it was computers talking to each other and people talking to computers by using them through the network. But I did realize that you should be able to connect from any location with any device. And that it should be very easy to use like telephone or electricity. You don't get how it's done. Electricity is a wonderfully simple interface. Plug in, you get electricity. This is much more complicated. And you can deal with it in a natural way. Right now the language, the interface, the human computer interface is too complex. So I saw that, but I didn't see the social networking side, that it would reach the consumer world.

钟布：那就是我想问你的问题。在我来这儿之前，我觉得，你的贡献非常大，你为网络建立起一个框架，通过提出这种精彩的队列理论，并帮助了分组交换，我说对了吗？
LK：是的，是这样的。作为工具和思考系统方式的队列理论是我主要的方向。另外，我从来没有上过队列理论的课，都是自学的，然后写了这些书。因为它是正确的度量标准，它允许概率方面有不可预知的流量，甚至有不可预知的网络或可靠性。线路来来回回，我需要运用这个理论并提出一种方法来围绕它建立一个网络。这就是分组交换的由来。所有的性能评估都是很多表现综合的，我不知道你是否看过这本书，中间也有许多遗传因素，但这里有我所有的数学知识，也有顶层逻辑结构。我还有模拟，在这儿，有大量的模拟，针对不同的体系结构、随机路由、分布式路由。这儿，我向你们展示理论结果和模拟结果，它们排列得很好，这和最终的结果是一致的。我进行了很多模拟，因为我必须在我的理论中做一些假设。这些假设是对的吗？你可以建立一个网络，只是太贵了，那就用模拟的。这就是 TX2 的作用。很多都来自大数定律。有一些东西可以用来假设网络。建立网络的想法，没有人在我所做的一切之后建立起网络这一事实非常令人失望。过了好几年才开始运作。是，这是我们期待的，它是一个很大的转折点。
钟布：所以那时，你想把那么多大学校园里的电脑连接起来时，你能想象有一天，所有人都会使用互联网吗？
LK：没有，我没有想到。（就像在 1908 年，有人说……）我没预测到那样的用途。正如我说的，我想的是电脑之间互相交流，人们通过网络和电脑交流。但我的确意识到，你应该能够从任何地点、用任何设备进行连接。而且它应当很容易使用，就像电话和电。你不用管它是怎么做到的。电是非常简单的界面。插上电源，就有电了。网络要复杂得多。你可以用自然的方式处理它。现在，语言、人机界面太复杂了。我预见了这一点，但没有预见到社交网络那一面，没预见到它会触及消费者的世界。

(1:56:22)
BZ: But you begin to use that said as a first time you ask someone, bring back your electric razor. So, about something else here. I would like ask a little, I think it's a big question: how to be a great scientist like you? When you talk to someone who start

something new and a lot of people get inspired to the scientist. But we know how to be a great one?

LK: It’s hard to define that. I can tell you the way I view the world and what I complained to my students about, and I’ll begin with something I said on that one documentary. I think computers are the worst enemy of critical thinking. Computers are very useful. They're great. They do a lot of things. But the problem is that they substitute for thinking. I'm going to give you an example. I give one of my graduate students a research problem: Tell me how the following wireless network performs. He said, “I’ll take it and I'll make a mathematical model. They may not be able to solve it mathematically, but they'll come in and they'll simulate it, say response time. And I’ll show you the number.” I said, “Oh, that's very good.” And I said, “Why does that look like a straight line here?” The student doesn't. “What is the level out here? What about the system?” “I don’t know.” “So what if I changed the capacity? I double the capacity. What happens?” All says the student, “I'll simulate it again.” And I say, “You fail because you don't understand what you've got. You've got numbers. You don't have any understanding and knowledge about it.” Because for the students, it’s too easy to get numbers out of a computer instead of taking the results. And this gets to answer now taking the results and asking yourselves, what is this telling me? (Interpret) and why is he behaving this way? And how can I use these results in another context that may be related? It’s all that critical thinking, evaluating. For example, as you probably know, most great discoveries are not made by saying “Eureka! I found it!” It’s more like, “That's funny. Why does it behave in that way? Let me look at it as most people. Look at the strange behavior, say that's baby. I don't want, I want to look at what I think it should be instead of investigating this unusual behavior, because that's where things happen.” So in answering the question to be a good scientist, you have to understand what you're working with and keep asking questions, “Why is it behaving that way? And how can I modify it? And how could I model what's happening?” If the system is too complex for me to get it up here, my head, simplify it, make some assumptions, try to get the essence of the structure. So then you can evaluate it and understand it, and then use those intuitive principles on the network. What are the engineering intuitions? And because if you don't have it up here in your head as opposed to piece of paper, you can't think of it. You can't generate new ideas. You can’t in the shower or while you fall in asleep, suddenly get an idea. All my exams are closed-book exams. Can't use any books. Students say, “What? What if I can't get part A of a ten-point question? I lose all the rest.” I said, “Don't worry in my exam. You can't get part A, I'll give it to you. Part As were three points. Of course, you get three points.” So they don't have to worry that they missed one little thing. You can have it, if you can get all the rest, because I don't believe bringing books into an exam or bringing the Google into an exam. That’s what I write to it, because you don't own that information.

钟布：但你是最开始使用它的，第一次，你要别人把你的电动剃须刀拿回来。还有一些其他问题。我想要问一个小问题，我觉得它是个大问题：怎么能成为一个像你一样伟大的科学家？当你和一个刚开始新事物的人交谈时，很多人都会从科学家身上获得启迪。但怎么才能成为一名伟大的的科学家呢？

LK：很难界定它。我可以告诉你我看待世界的方式，和我向学生抱怨的东西，我从那部纪录片中我说过的话开始吧。我认为，电脑是批判性思维最大的敌人。电脑很有用，它们很棒，它们做了很多事。但问题是，它们代替了思考。我给你举个例子。我给一个我的研究生出了一道研究问题：告诉我以下无线网络的性能。他说："好的，我要做一个数学模型。它们可能无法从数学上解决这个问题，但它们会来模拟它的，比如说响应时间。我将把数字告诉你。"我说："很好。为什么这儿它看起来像一条直线呢？"学生没说话。"这儿的水平是多少？系统怎么样？""我不知道。""那如果我改变容量呢？把容量翻倍，会发生什么？"学生说的就是："我再模拟一次。"我说："你不及格，因为你不明白你得出了什么。你有数字，但没有任何的理解和对它的了解。"因为对学生来说，从电脑中获得数字而不是计算结果简直太容易了，这让他们得到了答案，然后问问自己，这告诉了我什么？（要解释。）他为什么要这么做？我怎样才能在另一个可能相关的环境中使用这些结果呢？这些都是批判性的思考和评估。例如，你很可能知道的，大多数伟大的发现并不是说一句"有了，我找到它了"就出来了。更多的是说："这个很有趣，为什么会这样呢？还是像大多数人一样看看它吧，看看这种奇怪的行为。我不想……我想用我认为的方式来看待它，而不是调查这种不寻常的行为，因为事情就是这样发生的。"所以在回答这个问题时——如何成为一名优秀的科学家，你得知道你在研究什么，并不断地提出问题："为什么它会这样呢？我怎样才能修改它呢？我如何模拟发生了什么？"如果这个系统对我来说太复杂，没法研究到那一步，那就简化它，做一些假设，努力去理解这个结构的本质。然后你就可以对它进行评估和理解，并在网络上使用这些直观的原理。工程直觉是什么？因为如果你不把它放在脑子里而是把它写在纸上，你就不会想到它，你就不会产生新的想法。你无法在洗澡或睡觉时突然就有了个想法。我所有的考试都是闭卷测试，不能使用任何书本。学生说："什么？那第一部分 10 分的问题我丢了怎么办？剩下的部分就溃不成军了。"我告诉他们："别担心我的考试。你第一部分得不了分，我给你。第一部分有 3 分，那你就会得到 3 分。"他们不必担心错过了一些小题。如果你能写对所有其他题，就可以得分，因为我认为不能把书带入考场或是把谷歌带入考场。这是我定的规矩，因为你并不曾拥有那些信息。

BZ: You want that come from out of your brain.

LK：It’s got to come out of the brain. And the other side I mentioned it before, Shannon is a good example. And in some ways, the way I think it's the same way is the mathematical world in the physical world. And they meet and you have to be able to be adapted to both. I’ve worked in Claude Shannon’s office. Great mathematician. What was he doing? You'd have a differential gear in one hand and a Swiss army knife in the other, and be on screwing to understand how it works. When the mathematics you could do was it was magnificent. He was a master at both. And to be in both domains allows you to bring together the physical world and the mathematics to describe.

BZ: I got a very inspired by you mention about assumption. When we make assumptions, we have a nod of concern. Oh, my god, I will make a mistake. And here you encourage and go ahead and put those assumptions out or whatever test it works out, and then how it is. And then you learn from those kind of mistakes, all of this ridiculous assumption. And then you go back and you know, see where we are.

LK: So there's an interesting way in which people, this is the real world, network research. And what a scientist does is the first may do is they make a mathematical model, and then they try to solve that model, solution. And very often, it’s difficult to go from the model to an exact solution. You can make approximations or assumptions instead of spending your whole life trying to break this exact solution, which you may not ever get, make some assumptions right here. There's another place you can make an assumption is right here. The model you make can be simplified. You made it. And if you simplify, you may be able to get an exact solution or a better solution than the original exact model. But the only thing that matters when you're all done is this. How well is it? What predict what's happening in the real world? So you got to come back to these physical real world. That's very important. And in my dissertation, It’s actually uh, here I make an assumption, which is wrong. And I know what's wrong, but it was simplifying assumption. It’s called the independence assumption. Here it is, I have a whole section called the independence assumption. And I know it's wrong. But if I don't make that assumption, I can't get the solution. For many reasons people are still not solve it exactly. You make this assumption goes right to and you compare it to the real world. And did it matter? No. So that that was the kind of breakthrough. People make that assumption. And I simulate, I could see the important thing was to be able to show that you get a kind of smooth behavior here, whereas in certain structures you get this very unsmooth behavior very tight behavior. And by putting enough top logical uh, uh, diversity, you can force that to become smooth as you need. So you have to think a lot about it. You know what Einstein said? Famous quote, he said, “Make every problem as simple as possible, but no simpler.” Don't go all the way. Go enough to get the solution. It’s a beautiful thought, because if you stay with a very complex problem, you can't break through. But that's a kind of trick.

钟布：你想要那些信息来自他们的大脑。

LK：它必须是从大脑发出来的。我之前提到过，香农就是一个很好的例子。在某种程度上，我认为这也是物理世界中的数学世界。它们相碰撞，你就必须能适应它们。我在克劳德·香农的办公室工作过，他是一个伟大的数学家。他在干什么？他一手拿着差速器齿轮，另一手拿着瑞士军刀，正在拧螺丝，来了解它是如何工作的。当你能做数学运算时，它非常奇妙。他是这两方面的大师级人物。在这两个领域，你可以把物理世界和数学结合起来进行描述。

钟布：你提到的假设让我很受启发。当我们做出假设时，我们会有担心：天啊，我会犯错误的。这儿你却鼓励大家，把那些假设或其他任何的测试拿出去看看它们效果如何，然后看看它们会怎样。然后你从这些错误中学习，从所有这些荒谬的假设中。然后转回去，了解我们的情况。

LK：有一种有趣的方法，在这个真实世界的人们进行网络研究，科学家首先要做的是建立一个数学模型，然后他们努力去解出这个模型，找出解决方案。通常，从模型到精确解决是很困难的。你可以做近似或假设，而不是花费你的一生去试图找出这个精确的解决方案，你可能永远都找不到，就只能在这里做一些假设。你还可以在这里做一个假设：你做的模型可以简化。你成功了。如果你化简，可能会得到一个精确的解答，或比原始的精确模型更好的解答。但当你做完这一切后，这是唯一重要的事：它到底有多好？现实世界发生了什么？所以你必须回到现实的物质世界，这是非常重要的。在我的论文中，我做了一个假设，其实它是

错误的。我知道它是错的，但它是简化的假设，被称为独立假设。在这儿，我写了整整一章节的独立假设，我知道它是错的，但如果我不做出这个假设，就得不到解。出于很多原因，人们还没能完全解决这个问题。你做出这样的假设，然后把它和现实世界进行比较。这重要吗？不重要。但它是一种突破；人们做出那样的假设。我进行模拟，可以看出重要的是能够证明你有一种滑顺行为，而在某些结构中，你会有很卡顿的行为。通过加入足够的顶层逻辑、多样性，你可以让它变成你所需要的滑顺。所以你必须考虑很多。你知道爱因斯坦说过什么吗？他的著名引言："让每一个问题都尽可能地简单，但不要过于简单。"不要一直持续下去，只要得到解答就行了。这是一个美好的想法，因为如果你一直面对非常复杂的问题，就无法解决它。但这是一种技巧。

(2:04:43)
BZ: That's very, very good. That's very good there. Um, you have a question about the celebration. So we were really liking that the idea because our project is really sort of like a focus on 2019, which is the fiftieth anniversary of the year. Um, we'll really talk to UNESCO and computer history museum. It's a physical internet archives and we really want and make that a big day. And we also heard like the UCLA want to do something there. That's definitely we want to make it, um, be part of it, hopefully.
LK: So there are some ways in which we could cooperate like I say. Uh, we want to do it here because of the (because it's the birth place). But in September, the internet society is celebrating its twenty fifth anniversary and what they're doing is they're gonna hold it here. But because it's an international society, they're gonna begin some discussion here, and then they're gonna pass it around the world and observe in various countries around the world as the sun moves. And each of them will have a little project with the discussion to talk about in the final it will come back here at the time hours. You think about that model. It may be possible for us to do some presentations and celebration here, and then pass it to other places in the world. UNESCO is a good example of having access to many places. (So what date you would like to choose?) October 29. (But in 1999 and the thirties anniversary as it chooses the second of September.) Because at that point we hadn't focused on the first message. We focus on the first load. That's why. And we realized the more significant event was when we had a network.
钟布：那太好了，非常好。之前你说到了关于庆祝的问题，我们很喜欢这个想法，因为我们的项目重点是 2019 年，即 50 周年的纪念。我们要和联合国教科文组织及计算机历史博物馆谈谈，它是一个实体网络档案馆。我们非常想让这一天成为重要的日子。我们也听说 UCLA 想做点什么，那绝对是我们希望的，希望我们也能成为其中一部分。
LK：像我说的，有一些方法是我们可以进行合作的。我们想在这儿庆祝（因为这是它的诞生地）。但是在 9 月，互联网协会要庆祝它的 25 周年纪念日，他们打算在这儿举办庆祝活动。但由于它是一个国际性组织，他们会从这里开始讨论，然后在世界各地传播，按照太阳升起的顺序在世界不同的国家进行庆祝。每个国家都会举行一个小项目来进行讨论，最后它会回到这儿。你想想这个模式，也许我们可以在这儿进行一些介绍和庆祝活动，然后把它传递到世界其他地方。联合国教科文组织是一个很好的例子，能接触到很多国家。（那你想选择哪一天呢？）

10 月 29 号。（但 1999 年，30 周年纪念日时选择的是 9 月 2 号。）因为那时我们还没有把注意力放在第一条发送的信息上，我们关注的是第一次负载。这就是原因。我们意识到比那更重要的是我们拥有网络的时候。
BZ: So maybe we would like to spend a little bit more time in 1980s of your work. Um, let's start. So you actually help ARPA in Washington D.C. physically. You go there and work.
LK: I visit there. I didn't spend weeks there, but I was working very close with Larry. But we were chosen as the place where the measurement will take place. We can make any IMP generate artificial traffic. We could have any in collect measurements. We could trace a packet moving through the network, collect all of that, and then we could evaluate it. And I have a wonderful paper on this called "computer network measurements and modeling". I'll give you the reference if you like. Get your a copy of paper. Uh, on my website is… I'll send you a copy of that paper, which shows a week long data, measure data for a week. And we found a rather interesting phenomenon. I'll give you one example. Traffic goes from one node to another, but some traffic stays within the node, because one computer into the node to another computer at the same node. After all, what better interface between these two computers than the switch? We call that incest. You know what incest is? You know, in the same family, twenty two percent of the traffic at that time was incest, twenty two percent. Nobody saw that before. So you can discover things by making these measurements. And you have to do that. Now we were the network measurement center from 1969 to 1975. At that point, the defense communications agency DCA, took it over and they hardly ever measured anything again. Now, nobody knows what the internet is like. They don't have the topology. They have to discover it, and we've lost a lot of capability to understand it before, but we learned an awful lot in those early days. We could break the network anytime we wanted, discover a new fault and fix it. We'll tell BBN to fix it. At first BBN did not release the IMP code. So when we found something was broken, we tell BBN what happened. And they have to fix it. It would take six months. Then we got the code. We saw the break, we told them how to fix it. Still took six months, so the BBN and UCLA had a rather interesting dynamic. They wanted to keep network up and we kept breaking.

And that was the best, best thing to do, of course, because we found some very strange things that went on the internet. You may have heard of something example, uh, you know the … procedures such that. I'm in a node, if you want to send something to another node, you asked me, how long will it take to get there? And I asked my neighbor how long will it is. You see we pick the best route. One time Harvard said it has a zero delayed path to every other node in the network, so people would send it to Harvard. Harvard would send it out, come right back. Crash. It was a simple error in the writing table. Uh one day they double the storage capacity in the IMP, network went down. Why? Well, we figured out why. You think it couldn't hurt. But there was finally a very subtle reason why it went down. These things called Christmas lockup, the assembly lockup, store and forward lockup, uh lot of interesting and they are all described in my book, this book here.

And since there have been more problems as well. But the problem with the network now, I mean, I can tell you the network will fail. Some unknown problem will surface at some point with the right conditions. Um, it's too complex a system. (You don't have to be artificial bad intention to bring it down to something like too complicated, so many factors…) Traffic of a certain type requiring a certain performance. Um, there's a thinking of flow control. TCP is an example.

We determine how things can move in flow. And then somebody gets a little thing here to change flow control for their system. Another one here, somebody gets something and then not all the way of all the rest of the control. And they interact in ways you can't necessarily predict those kinds of things. The network is too complex now. Complexity is a curse, as you know, it should have been that all the controls afterwards in one concentrated package that we could examine. And it's not the case now. So there are ways to that's where the hackers take advantage of. They can explore its dependencies that other people are not necessarily seen.

钟布：我们想要多花点时间聊聊 20 世纪 80 年代你的工作，那就开始吧。所以你实际上帮助 ARPA 在华盛顿进行工作了；你去了那儿工作。
LK：我去访问了那里，并没有待太长时间，但我和拉里工作很密切。我们被挑选出来，选择测量的地点。我们可以让任何 IMP 产生人工流量。我们可以收集任何测量数据，可以跟踪通过网络的数据包，收集所有这些，然后对它进行评估。对此，我有一篇写得很好的论文，叫《计算机网络测量和建模》，如果你想要，我可以给你进行参考，给你一份论文复印件，上面显示了一周的数据，我们测量了一个星期的数据，发现了一个很有趣的现象。我给你举个例子。流量从一个节点传输到另一个节点，但一些流量仍然停留在节点内，因为它是从一台计算机到同一节点的另一台计算机。毕竟，这两台计算机之间的接口比交换机更好。我们称之为乱伦。你知道乱伦是什么吗？在同一个家庭里，那时有 22%的流量是乱伦，22%！之前没人知道。所以你可以通过测量来发现事物，而且必须这么做。从 1969 年到 1975 年，我们是网络测量中心。在那时，国防通信局（DCA）接管了它，他们几乎再也没有测量任何东西。现在，没人知道互联网是什么样的。他们没有拓扑结构，他们必须去发现它，而我们之前已经失去了很多理解它的能力，但我们在早期也学到了很多。我们可以随时中断网络，发现新的故障并修复。我们会告诉 BBN 来修复它。起初，BBN 没有释放 IMP 代码，所以当我们发现有故障时，我们告诉 BBN 发生了什么，他们就得来修，这要花六个月的时间。然后我们有了代码，我们找到了故障，告诉他们要如何修理，结果还是用了六个月。BBN 和 UCLA 的动态相当有趣，他们想保持网络畅通，而我们不停中断它。

当然，这是最好的办法，因为我们在网络上发现了一些非常奇怪的东西。你可能听说过一些，例如，程序，这些。我在一个节点里，如果你想发送东西到另一个节点，你问我要多久它才能到达那儿；我问旁边的人需要多长时间。你知道我们选择了最好的路线。有一次，哈佛说它的网络对其他每一个节点都有一条零延迟的路径，所以人们都把东西发送到哈佛，哈佛再把它发送出去，然后网络就崩溃了。这是写表中的一个简单错误。有一天，他们把 IMP 的存储容量增加了一倍，网络就瘫痪了。为什么呢？我们找出了原因。你觉得没什么关系，但最终它会瘫痪还是有一个非常微妙的原因，这些被称为 Christmas lockup, the assembly lockup, store and forward lockup，很有趣，它们都在我的书中有所描述，这本书。

从那之后也出现了更多的问题。但现在网络的问题是，我能告诉你网络将会失败。某些未知的问题会在合适的条件下出现在某些情况中。这个系统太复杂了。（用不着人为的恶意去破坏它，而是一些太复杂的东西会让它崩溃，有太多的因素……）某种类型的流量需要一定的性能，有一种想法是流量控制；TCP 就是一个例子。

我们决定事物如何在流量中移动。有人在这点上做了一件小事来改变他们系统的流量控制。另一点是，有些人得到了一些东西，但不是对所有其他东西的控制。你不一定能预测它们相互作用的方式；现在的网络太复杂了。复杂是一个诅咒，如你所知，它本应当是所有的控制都在一个集中的数据包中，可供我们检查。现在不是这样了。这就是黑客利用的方法，他们可以探索它所依赖的关系，而其他人不一定明白。

(2:12:59)
BZ: So I don't want to ask you, maybe it's too long for us to think we are celebrating the fiftieth anniversary very soon. How do you think about the next ten years of the internet? What’s gonna happen to it?
LK: Okay, so you are really asking two questions. First question you're asking, what will the infrastructure look like? Switches the lines, even the protocols. Second question you're asking is what about the applications will be the service and application. The first one is relatively easy to answer. The second one, we can’t answer. So let me give you an example for the first answer. Network, as we see, is going mobile, wireless, portable, distributed. And the endpoint, I believe, will be well, have essentially a pervasive, global, nervous system on this planet, with everything will be connected to it. Internet of things is beginning to produce that. And wherever you go, there'll be network awareness. All the devices will see where you are. Your privacy is gone. Don't know what you like to do, what preferences you have to mention before to be able to interact with it very easily the natural way. Uh, but everything would be what's pushing the internet of things, especially two things. One is the development is very small, embedded devices, logic processing memory display, microphone speakers, very small embedded in environment that can communicate using wireless and wired communications. And once we have that where you go, you get network accesses. Now in terms of the applications, we've been terrible at the predicting the major applications that have come along. The first one was the email. Nobody predicted the email in those early days. Finally, when they came about on 1972, within a few months, it took over the traffic of the internet. That's when we realize it’s people to people, not machine to machine. We didn't predict YouTube. We didn't predict the web. We didn't predict Facebook. We didn’t predict most of the major applications, Instagram and so on. So we have created a system called the internet, which will constantly surprise us, which is a good thing. It’s opportunities. Anybody can produce the next great application. But in terms of what great innovations have occurred over the last few decades, the kinds of hot applications we see are not groundbreaking. You know, sending a picture here and

there on Instagram, very popular, but the change of society, this thing has changed the way kids into the act now. But in terms of fundamental things like atomic energy, like the internet, like space travel. Where is the really big dog? Lot of those occurred in the fifties and sixties and seventies. We haven't seen that happen. We hope it will happen. But the applications these days are unpredictable. And I find out that is a good thing.

钟布：我不想问你，也许对我们来说，现在考虑 50 周年的庆祝还太早了。那你如何看待未来 10 年的互联网？会发生什么呢？
LK：其实你问了两个问题。第一个问题是基础设施会是什么样的？交换线路，甚至交换协议。你问的第二个问题是关于应用程序的服务和应用程序。第一个相对容易回答，第二个问题无法回答。对第一个问题，我给你举个例子。正如我们看到的，网络正在向移动、无线、便携、分布式的方向发展。我相信终点就是在这个星球上存在一个无处不在、全球性的神经系统，所有的一切都将与之相连。物联网正开始产生这种效应。无论你走到哪里，都会有网络意识。所有的设备都可以看到你在何处，你没有了隐私，不知道你喜欢做什么，之前你有什么偏好才能很自然地和它进行互动。但这一切推动物联网的东西，从根本上来说就是两样东西。一样是开发出来的非常小的嵌入式设备，逻辑处理内存显示，麦克风扬声器，在非常小的嵌入式环境里可以使用无线和有线通信进行沟通。一旦我们有了它，不管去哪儿，你都可以访问网络。就应用而言，我们一直都不擅长预测那些出现的主要应用。第一个是电子邮件。早期，没人预测到了电子邮件。最后，当它们在 1972 年出现时，几个月内，它就占领了互联网的通信量，这时我们才意识到，这是人和人之间的交流，而不是机器与机器之间的。我们没有预测到 YouTube，没有预测到万维网，没有预测到 Facebook，没有预测到大多数主要的应用程序，像 Instagram 等。所以，我们创造了一个叫做互联网的系统，它会不断地给我们带来惊喜，这是一件好事，这是机会。任何人都可以创造下一个伟大的应用。但就过去几十年出现的重大创新而言，我们看到的热门应用并不是突破性的。在 Instagram 上到处发照片很受欢迎，但是社会在变化，这改变了孩子们的行为方式。但就像原子能、互联网、太空旅行这样基本的事物而言，真正的大想法在哪里？它们大多都发生在上世纪五六十年代、七十年代。我们还没看到类似这些的出现，我们希望它能出现。但现在的应用程序实在无法预测，我觉得这是件好事。
(2:16:40)
BZ：Some like MySpace is already die. MySpace is already gone. Nowadays a lot of people also say Facebook will not be there for next five, ten years. And you begin to have some new things there. That's why Facebook keeps buying Instagram, hope everybody to another platform.
LK: But what we haven't addressed much of this discussion a little bit. It is the dark side of it. The internet is a problem. After all the power of the internet comes about as follows. It allows anybody with any device at any location to reach out to millions, hundreds of millions of people immediately at no cost in time, effort or money, anonymously. That's its power. That's also perfect formula for the dark side of the internet. It’s easy. It’s cheap, it’s fast, it’s pervasive and nobody's known you did, so that attract some of the wrong-minded people.

So what is happening now is we get not only hackers who are a nuisance and bother you and annoy you. That's bad enough. We get organized crime and we'll get nation states involved in this game now. And now it's very serious. So what's gonna happen? Well, there's a certain move these days to protecting oneself by taking your network away from the internet, creating private networks. And as that happens, unfortunately it’s a move into that direction. And that will balkanize the network and deceptive domains and the free internet access will begin to diminish, which I think is a great chain.

钟布：一些像 MySpace 这样的社交网络社区已经消失了。现在很多人也说，Facebook 再过五到十年也将不存在了，会有一些新的东西出现。这就是为什么 Facebook 一直在收购 Instagram 这样的软件，希望大家都能转到另一个平台。

LK：但我们在这次讨论中没有提到多少的是，这是它的阴暗面，互联网是个问题。毕竟，互联网的力量来自于此：它允许拥有任何设备的任何人在任何地点，都能以匿名的形式，立即联系到数百万人，数亿人，而不花费时间、精力或金钱；这是它的力量，也是互联网黑暗面的完美公式。它很容易、很便宜、很快捷、无处不在，而且没有人知道你做了什么，因此它吸引了一些有着错误思想的人。

所以现在发生的是，我们不仅有了讨厌的黑客来骚扰你，这已经够糟糕的了。我们还遇到了有组织性的犯罪，让整个国家都参与进来了。现在形势非常严重。那会发生什么呢？现在有一种保护自己的行动，让你的网络从互联网断开，建立起私人网络。随着它的出现，不幸的是，它是向那个方向发展的过程。它将会阻碍网络，欺骗性的领域和免费的互联网将会开始消失，我觉得这会有巨大的反响。

But that's one possible end point. Nations, corporations, individuals who protect themselves and they can't get access to many of the benefits that we enjoy so much. So what to do? So try to protect the network. Now there's two parts of the protection. One is within the boundary of the network itself. There are a number of solutions. There is basically software defined networks, named network is something called homomorphic encryption. I don't know if you're familiar with that, but it allows one to take a software program and data and encrypt them and without ever decrypt them, you can process the encrypted data in an encrypted program and get a result that's encrypted. And nobody ever sees the data in the clear. This is a research project. Now it's going on and hopefully eventually be able to get it down to reasonable overhead. That would be very powerful. Another way is to something I’m working on with another colleague is to go back to the first thing I told you was bad, the way the telephone network does, namely, before we get a conversation going, we set up a link and then we use it. Then we let go. The trouble with the telephone network back down is you couldn't set it up and take it down very quickly.

但那是一种可能的结果。国家、公司和保护自己的个人无法享受到我们现在享受的很多好处。所以要做什么呢？努力去保护网络吧。保护有两部分，一是在网络本身的界限以内，这有很多种解决办法。基本上都有软件定义的网络，命名网络就是所谓的同态加密，我不知道你是否熟悉这个，它允许你取出一个软件程序和数据并对它们进行加密，而不需要对它们进行解密，你就可以在一个加密的程序中处理加密数据并得到一个加密结果。没有人能够清楚地看到数据，这是一个研究项目，它现在正在进行中，希望最终可以把它的成本降到合理范围，那将会很强大。另一种方法，我和另一个同事正在做的，是回到我告诉过你的不好的

情况，就是电话网络的工作方式，也就是说，在我们开始对话之前，先建立一个链接，再使用它，然后由它去。电话网络的问题在于你无法很快地把它设置好或把它断开。

So while it's up, there's a lot of wasted time. Well, for want of a better term and I don't like this term, we now can do very fast circuit switching. If I want to send you a burst of data, we set up a direct connection with network goes through and we will break it down quickly, which means then different segments can be used by somebody else. That's almost like package-switching. There's no hop, there's no buffering. There is no queuing in the network, which means I know exactly how much capacity have available. If it's available for us, I give it to you, and we release if somebody else use, which means we can run the efficiency very high. Keep the response time down, predictable, almost no jitter, almost no very building with response time. And by setting up the connection in a kind of space time, protocol. What I sent to you does not have to have my address or your address. Its path is determined by when it gets to a switch in space and time, how it goes. So if you sniff that burst, and they're small, maybe eight bits. You look at this; you don't know where it came from. You don't know where it's going to. You don't know what else is the data. It doesn't even have to be encrypted. You see eight bits. What is that? So it gives you protection that way as well. You get security automatically. It’s a whole new architecture with a lot of sense. It's not packet-switching. It can ride on top of packet networks in a very clever way. So there are solutions to protect the network, but mostly violations occur at the edge where you and I, we don't encrypt very well. We don't use passwords very well. We copy the password on a post and put on the computer. We use the word “password” for a password. Well, I tell you what my password is. And on corporations, the way they get somebody to click on a link. Uh, that's where a lot of the problems that's not yet solved. And that we're working on that now as well. But that's much harder problem. (So that's something we're working on right now.) And I’m working on this part right now. The edge is much harder. It requires a lot of good hygiene on the part of the users as well.

所以，在它连上时，有许多被浪费的时间。我不喜欢这样，为了更好的结果，我们现在可以进行快速电路切换。如果我想给你发送一组数据，我们会直接和网络建立直接连接，然后快速把它分解，这意味着不同的段可以被其他人所使用，这几乎就像分组交换。没有跳跃，也没有缓冲，网络中没有排队，这意味着我可以确切地知道有多少容量可用。如果它对我们有用，我就把它给你；如果其他人要使用，我们就放开它，这意味着我们可以用非常高的效率运行。降低响应时间，能预测出时间，几乎没有抖动和构建响应的时间。通过建立一种时空连接，一种协议。我发给你的东西上面并不一定有我的地址或你的地址。它的路径是由时间和空间的转换决定的。如果你看看那组数据，它们很小，也许才 8 比特。你看看这个，不知道它从哪里来的，也不知道它要发到哪去，不知道这数据还有其他什么东西，它甚至都没有加密。你只看到了 8 比特。那是什么？所以这样它也给了你保护，你自动得到了安全。它是一个全新的结构，很有意义。这不是分组交换，它能以一种非常聪明的方式在数据包的网络上运行。所有是有保护网络的解决方案，但大多数情况下，违法发生在我们没有很好加密的时候，我们没有很好地使用密码。我们把密码复制到邮件上，然后放在电脑上。我们用“password”这个

词作为密码。我告诉你我的密码是什么。在公司里，他们让别人点击链接，这就是很多还没有解决的问题。我们现在也在致力于这个，但这是难得多的问题。（这就是我们现在正在做的事。）我现在正在这一块努力。它难得多，也需要使用者有良好的卫生习惯。

It is all kinds of multiple encryption, double encryption, etc. Quantum computing is another solution with already encrypted for you. And it can't be repeated one kind passwords. But this whole area is difficult. And the reason is we didn't build it into the network to begin with. What we should have done, I have told you these two things we should have done. One is we should have built him strong user authentication; if I claim to be me, it can be proven that it's me talking to you and strong file authentication. If I send you a file, you are sure it's what I sent you. It would not been changed or interrupted or whatever. We could have built that in early on and then turned it off, as I said, to allow people to participate until we got the critical mass going. And then we could have used it when the dark side began to appear. (Is that too difficult to build now?) You have billions of systems right now with the old protocols built in. It’s very hard to do that. If you're gonna do, it has to be compatible with the old while you introduce, which puts constraint, but so that's why homomorphic encryption is one solution for this part.

它是各种各样的多重加密、双重加密等。量子计算是另一种解决方案，它已经为你进行了加密，而且它不能重复一种密码。但整个领域都很困难，原因是我们一开始并没有把它构建到网络之中。我告诉过你，这是我们本应该做的两件事之一。一件就是我们应当为人们建立起强有力的用户认证；如果我自称是我，就可以证明是我在和你交谈，并有强大的身份验证文件。如果我发送给你一个文件，你就能肯定它是我发给你的，它不会被修改或中断或遭遇其他。我们本应当一开始就建立它，然后把它关闭，就如我说的，让人们参与进来，直到出现重大问题。当阴暗面开始出现时，我们就可以用上它了。（那现在建立太困难了吗？）现在已经有了数十亿的系统和旧的协议，很难再把它建立起来了。如果打算做的话，在你引入它时，必须与旧的相兼容，这就会带来束缚，也就是为什么同态加密是这部分的解决方案之一。

(2:24:20)

BZ: Good. We also want you to ask a question about China. China became rising very rapidly in the tech-war over there. Um, based on your observation, how do you think about the role of China will play in the tech world?

LK: It’s a good question. Certainly it's gonna be a dominant role. Um, for one thing, you have the capability in terms of the user base. You are your own market. China's Zhang Wan, as the United States was in its early days, that's one of the reasons the United States could rise so quickly. But now it is a global economy. But still China is unique. The fact that you're investing so heavily in education and engineers in plans in research laboratory is very different from what we and so that's admirable. I wish we could do more. The fact we're doing just the opposite in this country, limiting immigration is a bad idea. The one thing as you're well aware is that the Chinese educational system right now. Teaching students to pass the examination. It’s commonly no problem instead of being innovative and thinking out of the box. And

I’ve been in China discussing with some of the educational groups to bring in some of the innovative, the viewpoint that western students can't have. Ah, they're much more creative because as children had been brought up to challenging question because nowadays with the competition so severe to get into a good university. America is moving more to passing the exam instead of running much. But I see in my own students that the western student are more willing to challenge something the more willing to try a new approach, but less willing to take the directorate and do the work of solving the problem that can be solved. I remember giving exams a few years ago and Asian students, a particular click click click answer. American student would say, “Well, if I had to solve this, here is the approach I would use.” And they don't do it, but the same student to say, “If you give me a different problem here, here is how I would approach it.” It was the Asian student who needs to be fed the logically the algorithm issue. That's changing. I think it’s changing a lot. Another story. You will appreciate this. Many years ago, I had a class. I gave an exam and a Chinese student came up to me. The midterm, he says, and he squeezed two or three more points out of me. He said, “Ah, now I’m number one in the class.” I said, “No, you're number two.” He said, “First among the Chinese.” And that was the attitude. So I found it very interesting. It was a very good student, but that's all that mattered. I don't know if that's still the case today.

钟布：好的。我们也想问你一个关于中国的问题。中国在技术战争中发展得很快。以你的观察，你如何看待中国在技术世界中将会起到的角色？

LK：这是个很好的问题。当然会是占主导地位。首先，你们在用户基础方面有实力，你们就是自己的市场。中国和美国早期阶段一样，这是美国能如此迅速崛起的原因之一。但现在是全球经济，可中国仍然是独一无二的。事实上，你们在教育和工程上投入了相当大的资金，投在研究实验室的计划中，这和我们显著不同，这是令人钦佩的。我希望我们也能做得更多。而我们现在在美国所做的却恰恰相反，限制移民是个糟糕的主意。还有一点，你们都很清楚的，是中国的教育体制。教学生通过考试，而不是具有创新思维，一般来说没有问题。我一直在中国与一些教育团体讨论引进一些创新的观点，这是西方学生所不具备的。随着当今考取一所好大学的竞争如此激烈，向孩子们提出了具有挑战性的问题，所以他们更有创造力。美国正在更多地让学生通过考试。但我从自己的学生身上看到，西方学生更愿意去挑战，更愿意尝试新方法，但不太愿意担任董事会成员，或是做一些可以解决问题的工作。我记得几年前给学生考试的时候，亚洲学生就一通点击答案，美国学生会说：“如果非要我来做这个，这是我会使用的方法。”他们并不会去做，但会接着说：“如果你给我一个不同的问题，这是我会如何解决的办法。”亚洲学生需要从逻辑上解决算法问题，那就是改变。我认为现在已经改变了很多。还有一个故事，你们能明白的。很多年前，我上过一门课，考完试，一个中国学生来找我，这是期中考试。他从我这儿要走了两三分，然后说：“啊，现在我是班里第一名了。”我说：“不，你是第二名。”他说：“中国学生里的第一名。”这就是他的态度，我觉得很有趣。这是个很优秀的学生，但那才是最重要的。我不知道今天是否还是这样的。

BZ: Ok. But you have some Chinese student here with you. Right? (Yes, many. Look at the list.) There's like a trend among your Chinese student and other students. There's some difference between them?

LK: Less and less. Uh, it used to be that you couldn't trust the references coming out of China. They were way overstated. Now it's more realistic. For one reason is many Chinese students are returning to China. You know, Taiwan was the first place to bring their students back. I noticed that. And the way they did that is they created this entrepreneurial park with many advantages, good funding, good laboratories, good facilities. Chinese students, now some of them are going back, or they spend a few years here and then go back and so get the American experience. And the idea of how to start a company, how to do research. And so that is changing quickly. So I see China is a major player, um, the trick is to make it a cooperative play. I just read the paper yesterday that China has found some other way to restrict access to the internet from within China. (They don't allow to use vpn.) That's right. So I know my Chinese students, they tell me they can very easily get on to the open internet. But every so often they run into a block. I communicate with someone, and sometimes we can't share some information. They can't get access to information to be able to share it with me. It's changing. But China certainly is a key player these days. And for the reason I said the investment in education and technology, it's wonderful to see. It's very important.

钟布：好吧。你也有一些中国学生，是吗？（是啊，有很多。看看这张名单。）在你的中国学生和其他学生中间，是否有区别？

LK：区别越来越小。过去，你不能相信来自中国的推荐信，它们都言过其实；现在越来越贴近现实了。原因之一是许多中国学生都开始回国了。我注意到台湾是第一个把他们的学生带回去的。他们做到的方式是建立了创业园，有很多优势、充足的资金、优秀的实验室和优良的设施。一些中国学生回国了，或者在美国待了几年、获得了一些美国经验、如何创业、如何做研究，然后回去了。这种情况正在发生迅速变化。我知道中国是一个主要的参与者，关键是要让它成为合作伙伴。昨天我刚刚读到一篇 文章，说中国已经找到了其他方法来限制国内互联网的接入。（他们不允许使用 VPN。）对，我知道我的中国学生，他们告诉我他们可以很容易连上网，但偶尔也会遇到障碍上不了。我和他们一些人交流，有时我们无法分享一些信息，他们无法获取我分享给他们的信息。这在改变，但中国无疑是当今一名关键的参与者。就像我所说的原因，很高兴能看到它对教育和技术的投资，这非常重要。

BZ: So you already told me your typical life and where you were in the city college New York. What's your typical life today?

LK: Okay, I stopped teaching a few years ago because I want to have more flexible time and I'm still supervising PhD students, still doing research, having a paper in the press right now. And working with the school here, the school of engineering to help direct what the major goal should be as well as the universities. I'm on the board at city college New York, help them. And so I'm looking at the larger picture. And as you should go in terms of investment of resources. But I'm still doing research as well. But it's not a daily schedule. I spend two to three days a week in the university, but I travel a lot. I give lectures in many places, and I love to teach. And I'm not teaching a regular class right now, because I don't want to be tied up ten weeks in a row. But I start teaching this again and may revise this book (but you have some book plan). In the back of my mind. I want to revise this book, but I'm also spending a lot of time keep myself physically fit as well. I always have them, takes a lot of time. (What do you do for exercise?) Well, I do Japanese Karate, the conqueror need a second degree, doing that for a long time. And that gets back. I said I'd get back to this in New York. I tell you, you have to learn to take care of yourself in the street. Right? One day I took Larry Roberts to a place here in Los Angeles called Watts Towers. It's a very big neighborhood, eastern LA and there was a very interesting glass structure there that somebody put together. And I was walking there with him and I looked down in an alley and I saw some people spying using techniques. I realized I couldn't defend against. And at the time I was doing marathon running. So I decided I'd better learn how to do this. So I have to running the number of miles. I came to UCLA one of the physical education classes. And I said to the instruction, "Where is the best place to learn self defense?" And he said, "Right here." and I'm still there. He has a private doge of campus. I do that three times a week. (You must be already black belts there.) Yeah. Second degree. (I also did it, Oklahoma.) That's different, but they're all similar; it's wonderful.

BZ: So you when you are young, you were involved in a street fight? (Not a game.) You're tough.

LK: Tough one? I don't know. Surviving. I never joined the gang.

BZ: Can you tell us your siblings? How many siblings?

LK: I have one sister. She's older, two and half years old. She lives in Pennsylvania now. (Oh, in my state.) Yes, that's right. And she became a psycho therapist. She's retired now. (So you must be a big protector for her.) I don't think so. (While you were young, if you go to the tough neighborhood.) Look, the neighborhood where I saw people killed in the streets, nowadays that's not so uncommon, but it was because in Washington Heights, Manhattan, there is a major street Broadway in my neighborhood. On the west side of Broadway was richer people and safer. On the east side, poor people, and much more dangerous. I was on the east side, so I had to take care of myself. And it fights. You learn to use your head anywhere.

钟布：你已经告诉我在 CCNY 读书时的典型生活了。那现在你通常的一天是怎样的？

LK：我几年前就不再教书了，因为我想要更灵活的时间。我还在带博士生，还在做研究，现在还在发表论文。我和这儿的学院合作，工程学院，还有大学，帮助指导他们的主要目标。我是 CCNY 董事会成员，也为他们提供帮助。我看的是更大的愿景，在资源投资方面。但我仍然在做研究，只不过不是每天都做。每周我在大学里待两到三天，经常出差，在很多地方进行演讲。我热爱教书，只是现在不教常规课程了，因为不想连续十周都脱不了身。但我又开始教这个了，可能会把这本书修订一下（你还有一些出书计划？）。在我心里，我想修订这本书。我也花了很多时间来保持身体健康。我一直在坚持锻炼，花了不少时间。（你做些什么运动？）日本空手道，我已经是黑带两段了，练习很久了。我说在纽约我还会用到它的，我告诉过你，你得在街头保护好自己，对吧？有一天，我带拉里 罗伯茨去了洛杉矶一个叫瓦茨塔的地方，那是一个非常大的社区，在洛杉矶东部。那儿有一个很有趣的玻璃结构，是人们把它组装起来的。我和他在那儿走着，看到了一条小巷，有人在那儿用技术进行间谍活动。我意识到自己无法防卫，那时我在跑马拉松，所以我决定我最好还是学习怎么自卫。我跑了好多英里，来到了

UCLA 的一节体育课堂上，对老师说："哪里是学习自卫的最佳地点？"他说："就是这里。"我现在还在那儿学习。他那儿有私教课，我一周去三次。（你一定是黑带了。）是的，二段。（我也学了，在俄克拉荷马州。）略有不同，但都类似；非常好。

钟布：你年轻的时候参加过街斗？（不是闹着玩的。）你真强悍。

LK：强悍？我不知道。只是为了生存。我从没加入过帮派。

钟布：能说说你的兄弟姐妹吗？你有多少兄弟姐妹？

LK：我有一个姐姐，她比我大两岁半，现在住在宾夕法尼亚州。（和我在一个州。）对，她是一名心理治疗师，现在已经退休了。（所以你一定是她的保护神。）我不这么认为。（你年轻的时候，如果去了治安不好的社区……）我目睹了人们在街上遭到杀害的社区，现在这种现象并不少见，但那是因为它发生在曼哈顿的华盛顿高地。我家社区有一条百老汇大街。百老汇西侧的人更富裕，那儿更安全。而东侧是穷人，要危险得多。我就住在东侧，所以我必须照顾好自己。遇上打架，就得学会随时出手。

(2:34:04)

BZ: But also doing more exercise than keep you fit. Like the retirement, in your thinking, say something?

LK: Retirement is death.

BZ: How many hours you work nowadays?

LK: Um, typically ten hours doing one thing or another, maybe more. But exercise takes typically an hour and half or two a day.

BZ: But you also advise some PhD students. How many students?

LK: Right now I have none. I finished my last one couple of years ago. Problem in getting a good PhD student now is that I'm not teaching. Teaching in the class, you can see the good ones. And so now it's hard to evaluate that. I used to have eight. Now, just none.

BZ: Okay, so in my college and we usually have like a two way sort of choices. What I mean is, I guess students sometimes go to you, and then you said yes or no. Or sometimes, I usually don't approach students. So, but someone were approaching you, are you going to say yes or no? Or you have to evaluate? (Of course I evaluate.) How many years, usually they'll get their PhD done?

LK: Typically four years. But I have records of all the grades of all the students that I was teaching. I can see who are the good ones in the class and exams. And if anyone who came to me and I had space, I would take one, the good one, but I wouldn't go seeking. If they need to "I want to work with you", which another piece of the answer that I didn't give is "I'm starting a laboratory here called, you know, the MIT media lab? (Yes.) I'm starting here. Something called the connection lab." Similar idea. It's an environment in which ideas can be created in which young students can join, participate, exchange ideas, and the idea of the world connection. I think it's a good name; it means two things. One is networking, internet; and the other is connecting between people. And I'm looking for funding for that right now. It's a potential, but we still waiting to get done. And the thing is very interesting is we're going to get a large space. One of the things that connection lab do is it will allow incoming PhD students to be funded for one year. Typically, when the PhD student comes in, the first thing I look for is funding. They go to professors with money, said, “I want to work for you.” Whether or not the technologies what they want, but the money is there. It’s unfortunate for the student this way. We let the student come in for a year and look around to find out where they want to work and get to know the professors instead of going for them first. In addition, we have as part of the connection lab is something, we already started called internet research incubator. It’s based on the premise that in the undergraduate population, both in engineering, in science, humanities, business, math and languages, the undergraduate students, some of them have the brilliant ideas that they'd like to follow, creative ideas, but they can't get funded. They can't get a professor. They can't get lab space. They can't get a mentor and they get busy working in the cafeteria and the classes come on and those ideas die. So we wanted to help nurture that. So one of our alumni computer science alumni, put some money forward and when they entering the second year, we've created twelve prizes. The prize is fifteen thousand dollars for one year and lab space and access to professors and a mentor from either within the university or outside to work with. So what we do is we advertise it's all over the university, present an idea that you're passionate about that has something to do with internet no matter what, doesn't have to be technology. It can be social issues. It could the government issues whatever. Present it. And we've selected already twelve mentors. The mentors look at these applications. They say, “That's the one I want. That's the winner.” instead of saying “what your grade point average, what's your background?” Now let the mentor, he gets excited. That makes a good match. To win the second year right now. And that internet research in Tibet is part of the connection lab. It’s one of the elements. (So that's what keeps your hands full, keep you so busy?) Yeah, keeping busy is the best thing. You stay young, challenged, alert.

钟布：那得比保持健康还努力运动。在你认为，退休是什么情况？
LK：退休就是死亡。
钟布：你现在一天工作多少小时？
LK：一般十小时左右，做做这个，做做那个，也许还不止。但锻炼每天要花上一个半到两个小时。
钟布：你还在指导博士生吧，现在带多少学生？
LK：现在我一个也没带。最后一次带博士生是几年前了。现在要带一个好的博士生的问题在于，我不教书了。在课堂上教书，你能看出好学生，所以现在很难评估了。我过去通常是带 8 个，现在，一个都没了。
钟布：在我学院，我们通常有两种选择方式。我的意思是，也许有时学生会来找你，你会同意或拒绝。有时，我通常不会去找学生。但当学生来找你时，你是直接同意或拒绝，还是要评估呢？（我当然会评估。）通常他们要用多少年才能读完博士学位？
LK：通常是四年。我有教过的所有学生所有成绩的纪录。我能知道谁在班上和考试中表现好。如果有人来找我，而我有能力，会接收的，好学生。但我不会去主动找。如果他们需要，“我想和你一起工作”，那我不会给他们的一种回答是，“我在这儿开了一间实验室，被称为 MIT 媒体实验室。”我就在这儿开始的，

它被称为连接实验室；类似的想法。这是一个可以创造思想的环境，年轻学生也能加入、参与、交换想法和对世界连接的想法。我觉得这是个好名字；它有两种意思：一是网络，互联网，另一种是人与人之间的联系。我现在正在为它寻找资金。它还在进行中，我们还在等待有人投资。很有意思的是，我们会得到一个很大的空间。连接实验室做的一件事是，它能让即将入学的博士生得到一年的资助。通常，当博士生入学时，我首先要找的是资金。他们拿着钱去找教授，说："我想为你工作。"不管技术是否符合他们的要求，但钱就在那儿。这对学生来说是不幸的。我们让学生来一年，看看他们想去哪儿工作，再去了解教授，而不是先去找教授。另外，作为连接实验室的一部分，我们已经启动了互联网研究孵化器。它的前提是，在本科生中，无论是工科、理科、人文、商科、数学和语言，这些本科生中的一些人有很好的想法，创造性的想法 ，但他们得不到资助，找不到教授，找不到实验室，也找不到导师；终日在食堂忙着工作，忙着上课，这些想法就消失了。我们想帮助他们培育它。我们的一位校友，计算机科学的校友，捐了一些钱。当本科生到了大二时，我们有 12 种奖励。一种是一年 15000 美元，加上实验室空间，可以选择校内外的教授和导师。我们所做的就是在大学里做广告，让学生提出一个你感兴趣的想法，不管它是什么，都得和互联网有关，不一定得是技术，可以是社会问题，政府问题等等。提出想法；我们已经选择了 12 位导师，他们会查看这些应用，然后说："这是我想要的，这是赢家"，而不是问"你的平均绩点是多少，你的背景是什么。"让导师兴奋起来，这是个很好的搭配。现在就可以赢得大二的奖励。西藏的互联网研究也是连接实验室的一部分，是其中一个要素。（那就是让你忙碌的原因吗？）是的，保持忙碌是最好的事，能让你保持年轻、充满挑战和警惕。

（2:39:33）

BZ: So we usually say a great scientist a great professor usually bring or actually keeps your brain sharp. I was always like a new active. Your brain is active using more and brain cells like a re-energized. You know, um, you look exactly like that way. Well, yeah, what so you know, you don't think like a slowdown more the better. Okay. Um, you know I'm going to start retirement. You know so many computer scientists like to do this and all other father of internet, three others not much involved in start off. So go to commercial sort of monetize.

LK: Last month Larry started some as is said, Vint not really, he's with big companies. And Bob Kahn has his one company, CNLI, which he spent a lot of time. So different views. (How about yourself?) Yeah, I've done some startups, some successful you may not know. But I was one of the founders of company called Linkabit corporation. Probably never heard of them. The Linkabit have three founders, myself, Andy Terbium. You probably don't know and Erwin Jacobs. Erwin Jacobs with the founder of QUALCOMM. So the three of us formed Linkabit. And then Andy and Erwin took the company down to San Diego. They left their faculty positions, Erwin was at MIT and Andy was here in UCLA. I stayed here, Linkabit became very successfully. They sold it. I had a small piece of it still. They took that money and they started QUALCOMM. Terbium and Jacob started QUALCOMM. That was a very successful startup. Nineteen sixty eight, we began, nineteen sixty eight, very early. Formed a company called Nomadics, which is now deploying

internet access devices all over the world. It’s now owned by DOGMA. I started a few others as well. Some of those were successful. (So your major effort is still under research.) I would never leave it, I could have gone with Linkabit. Didn’t want to because that was when sixty eight. Ok, early 1969 that’s when the internet began. I never set out to make a billion dollars. I've done very nicely for a variety of other reasons, but the intention was never to exploit the system. The challenge I have is a good engineering balance.
BZ: I just want ask you if you want everything one more time once again, what things you like to not do or want to do, but you do not do.
LK: I wouldn't have gotten married so early. (How many children do you have?) I have two. And my wife has two. This is the second marriage, six grandchildren. I would have spent more time with my children. And unfortunately, grandchildren, they grew up east coast, except for one on the west coast. And we spent many years with her. More time with family. You know, the era I grew up as opposed to you, the father typically wasn't that involved with the children. Now it's very different. And now it's much better way. Because I totally devoted all my effort to this work.
BZ: So your first marriage ends because of divorce? (Yeah.) All right. So any children follow your career path?
LK: So when my two children, one got his PhD in scripts. Oceanographic institute is in oceanography. The other one almost got a PhD at Cornell in physical chemistry, but she didn't finish the work. She works with me on another company I started which is a conference company seminars. And she attends every one of the four meetings a year. It takes all; it’s about emerging technologies two to five years out that all information invites up a major report on each one of them. So she is constituted high tech work, very capable. (You can spend some time with your grandchildren also.) Oh, yeah, as much as I can.
钟布：我们经常说，一个伟大的科学家，一个伟大的教授，通常会保持大脑的敏锐。我也总是很积极。你的大脑用得越多，就越活跃，大脑细胞使用越多，就像重新激活一样。你看起来就像那样。你不像年龄增大而减慢了节奏那种。很多计算机科学家喜欢这么做，其他所有的互联网之父，另外三个，都不太参与开公司，商业化、货币化。
LK：上个月，所说拉里开了一家公司；文顿没有，他在大公司工作。鲍勃·卡恩有一个公司，CNLI，他花了很多时间在上面。大家有不同的观点。（那你呢？）我干过一些创业，有一些挺成功的，你可能不知道。我是一家名叫 Linkabit 公司的创始人之一。你可能从没听过。Linkabit 有三位创始人，我自己，安迪·特宾——你可能没听过，还有欧文·雅各布斯。欧文·雅各布斯是高通的创始人。我们三人创立了 Linkabit，后来安迪和欧文带着公司去了圣地亚哥。他们离开了教职岗。之前欧文是在 MIT，安迪在这儿，UCLA。我待在这儿。Linkabit 非常成功，他们把它卖了，我现在还有一点份额。他们用那笔钱成立了高通公司。特宾和雅各布创立了高通，那是一家非常成功的创业公司。1968 年，我们开始的；1968 年，很早了。我成立了一家名为 Nomadics 的公司，它目前正在全球各地部署互联网接入设备；现在它归 DOGMA 所有。我还成立了一些其他的公司，其中一些成功了。（所以你的主要努力仍在研究之中。）我永远都不会离开它，本来可以离开 Linkabit 的，但不想那么做，因为那是 1968 年。在 1969 年初就有了互联

网。我从来没有打算赚上十亿美元。由于各种各样其他的原因，我已经做得很好。但我的打算是永远不要去剥削这个系统。我面临的挑战是好的工程平衡。
钟布：我想问问你，如果你想要一切再来一遍，有什么是你不想做的，或什么是你想做但没做的？
LK：我不会那么早就结婚。（你有几个孩子？）我有两个，我妻子有两个。这是第二次婚姻；6 个孙辈。我会花更多的时间和我的孩子们在一起。不幸的是，我的孙辈，他们在东海岸长大，只有一个在西海岸。我们和她一起生活了很多年。我想要更多的时间和家人在一起。我成长的时代和你们不同，那时父亲通常不会和孩子关系太密切。现在非常不同了；现在的方式要好得多。那时我全身心地投入到这项工作中了。
钟布：你的第一次婚姻是离婚告终的？（是的。）有孩子选择了你的职业道路吗？
LK：有两个孩子，一个拿到了博士学位，在海洋学研究所从事海洋学研究。另一个在康奈尔大学，差一点就获得了物理化学博士学位，但她没有完成。她在我创办的另一家公司工作，那是会议公司研讨会。一年四次会议，她每次都参加。所有的信息都是关于两到五年后的新兴技术的，都各自需要一份主要报告。所以她是一个很有能力的高科技工作者。（你也可以和孙辈们在一起。）是的，尽我所能。

(2:44:33)
Someone: Yeah, any questions from just the whole that usually questions we can wrap up and would you like to see a little uh, a little about your club reduce the shore and you can language arts become continually that we posted it. I'm pretty much the man of hunters theory bye to you that when doing things in fact controls. How did that work out?
LK: So the question is, let me just check my schedule…So Larry Robert and I met each other at MIT as graduate students. We are both part of the staff at the MIT Lincoln laboratory staff associate program. So we shared in office. We are office mate as well as classmates. Larry was always a very detailed, the compiler for the TX2 computer. And he looked at every bit of every instruction to see what they would do it, how can how we could explore it. That was not my strength. I was more interested in more theoretical, more formative evaluation. Larry did his PhD on three dimensional graphics and how to find hidden objects. He is a more practical guy. He's very focused on what he was doing. I look at what I'm doing very carefully, but I'm aware of the outside influences as well as the impact. So I'm, again, much more than mathematical type, but he has a very good intuition. And he's very smart, very smart. So we got along very well. We all did a number of interesting projects together. For example, we put together a blackjack system, and there's wonderful stories about how we got from made some money in blackjack in Las Vegas and we've been thrown out of a number of clubs because you didn't call it cult. We also had a project to collect silver coin. Did Larry tell you about that? (No.) We collect a silver coin, when a quarter was worth more than twenty five cents if he melt it, but you couldn't. So we collected a lot until you could melt them. We tried to create a system to play the lead. When the ball goes around the raceway, it obeys Newtonian mechanics. And if you know how fast it's going, you know exactly when it's going to fall in; if you can

predict which half of the wheel is going to fall into, you can get two to one odds in your favor. So we try to measure the speed of the wheel and the speed of the ball. So in order to do that, we put a microphone in Larry's hand and wrapped it up like he had a broken arm and a recorder in his pocket. And he and I went to the system in LV, and he put his hand right next to the wheel so you could hear the ball going on and I'm betting. And unfortunately, I started to win. You know, it's Johnson; I started to win pretty nicely. So I'm winning. They saw Larry and me walking together and his hand is over here, next to the wheel. So the pit boss takes Larry's spoken army and pulled it. He says, "Let me see your arm." And Larry and I got worried because inside is a tape-recorder. We weren't defecting the wheel, but doesn't look good. So we ran out of there. Would have been very dangerous, but the blackjack won't win when we come there, when we start winning, they throw us out and they remember our faces.

某人：（问题很不清楚）这是怎么回事？
LK：你的问题是，让我看看我的日程表……所以我和拉里 罗伯茨是在 MIT 读研时认识的。我们都是 MIT 林肯实验室员工助理项目的成员，所以我们在一间办公室工作，既是同事，也是同学。拉里总是非常注重细节，他负责 TX2 计算机编译器。他研究每一条指令的每一个细节，看看它们是做什么的，我们要如何去探索它。那不是我的长处。我更感兴趣的是更理论化、更形成性的评价。拉里的博士主要研究三维图形学和如何找出隐藏的物体，他是一个更实际的人，非常专注于正在做的事。我也对自己在研究的东西很专注，但我会意识到外界的影响和效果。我不仅仅是数学类型的人，但他拥有很好的直觉，非常非常聪明。我们相处得很好，一起做了很多有趣的项目。例如，我们建立了一个赌博系统，有许多关于我们如何用这套系统在拉斯维加斯赚到钱的精彩故事，还有我们被许多赌场扔出去的故事。我们还有一个项目，是收集银币。拉里跟你讲过没有？（没有。）我们收集一枚银币，25 美分的。如果把它熔化了，硬币的的价值就超过 25 美分了。我们收集了很多用来熔化。我们努力创建一个系统来担任重任。当球绕着跑道旋转时，它遵循牛顿力学。如果你知道它的速度，就能知道它会落在什么地方。如果你能预测它会落入轮盘的哪一半，就能得到 2 赔 1 的概率。所以我们试着测量轮盘和球的速度。为了做到这一点，我们在拉里的手中放了一个麦克风，并把它包了起来，就像他胳膊断了一样；在他口袋里还放了个录音机。我和他去了拉斯维加斯，他把手放在轮盘边上，这样就能听到球的声音；而我则下注。不幸的是，我开始赢钱了。你知道，这是约翰逊；我开始赢得很多。他们看到我和拉里走在一起，他的手放在那儿，放在轮盘边上。所以老板抓住拉里的断胳膊并把它拉了出来。他说："让我看看你的手臂。"拉里和我很担心，因为里面有个录音机。我们并没有改变轮盘，但看起来不太好。所以我们跑了出去。这本来相当危险。我们到赌场后，开始赢钱，他们就把我们扔出去了，还记住了我们的样子。

(2:49:09)
So Larry and I have had a bunch of capers like that. We started a number of… I've been involved in his companies as well. That's investment, but he tried to make some major networking companies using new chip technology and new architecture technology. He's very famous for the kind of graph he makes. I don't know if you are aware of this, he'll typically plot log anything. Show a very important trend. And

he's amazing. His intuition is wonderful list to how to expose behavior on these various plots. He's the one who recognize that the cost of communications was coming down slower than the cost of switching. And when the cost of a switching drops below the cost of communications, that's when packet switching should have happened. Because that is a switch when its cost is less than the lines that it's controlling. You want to introduce something complicated, like packet switching. He recognized when that economic crossover occurred. And so he looks at those kinds of number. I'm not sure I answered your questions, though. He played a nasty trick on me once. TX2 at MIT Lincoln lab. Very expensive machine, an experimental machine. And it's a little registers about that big on a panel. So you got a bunch of these and I would get the machine late at night for midnight to seven am all for myself to try my program four days a week. So my sleeping was crazy. And when you have a machine all to yourself late at night and you're tired and it's an expensive machine you’re responsible for. You get to know the way it behaves. And you understand every sound. You know all it means. And I was there one night and I heard a sound I didn't hear before and worried me. I thought something was about to break. Be my fault. And then I looked at the control panel, and one of these registers was missing. It was an empty slot. And what did I see? Two eyes looking at me. It was Larry back. I could have killed him.
拉里和我有许多这样的事。我们开始了许多……我也参与了他的公司，那是一笔投资，但他想让一些大型网络公司采用新的芯片技术和新的架构技术。他以制图而出名。我不知道你是否意识到了，他经常能绘制出任何东西，显示出很重要的趋势，简直是太神奇了。他的直觉极佳地表达了如何在不同的情节中显示出行为。他认识到，通信成本的下降速度要慢于交换成本。当交换成本低于通信成本时，分组交换就应当发生了。因为那是一个交换机，它的成本比它控制的线路还低。你需要引入一些复杂的东西，比如分组交换。他意识到经济的转变会在何时发生，所以他看看那些数字。我不确定我是否回答了你的问题。有一次他捉弄了我。MIT 林肯实验室里有一台 TX2，非常昂贵的机器，是一台实验机器。一块面板上有这么大的寄存器，有很多这些的寄存器。每周四天，我可以从午夜到早上 7 点可以全权使用这台机器来尝试我的程序，所以我极度缺乏睡眠。当你有这么一台机器全供你一人在深夜使用，你又很疲惫，机器那么贵，你得负责。你会了解它的行为方式，你理解它每一个声音，知道所有声音的意思。有一天晚上，我在那儿，听到了一种之前从没听过的声音，所以我挺担心，以为有什么要坏了，那就是我的错了。然后我看着控制面板，其中有个寄存器不见了，那儿是个空槽。我看到了什么？两只眼睛透过空槽盯着我。是拉里回来了。我都想杀了他。

Someone: Yeah, so one last question before we wrap up. So we talk about are you worried about um, dark side of the internet? And today one thing that studying you're more media public attention is the dark web. And there's some information suggesting what we know about the dark web is only the uh, the tip of the iceberg. Yeah, people making this thing to be increasing very malicious, very evil things that what can be done to terminate existence of undercurrents, underworld?
LK: It’s a difficult issue because the internet is more complicated than just this dark web site. It’s got what's called a bowtie structure. Comes in central now network and

comes out anything inside the center can reach anything else inside the center. Things on this side of the bowtie, they can come in, but they can't return to this. Things here can leave the central network go out. We can't go back in here. And then there are some spans like this. And one piece of that is the dark web where you can access it from the global internet. It’s got protection. It’s very hard to come back. The trick is you don't want to enter it if you don't know what you're doing, and there are things going on there, a lot of the anonymous will be going on there, towards an example piece of it. The onion router where anonymity is supreme there. You can't stop people from producing evil effectively. And the dark web is a piece written and there were those who are experts using them, the hackers are very... They're always one step ahead of you. You only know that they do. You don’t know when they do it. And so it's a very difficult situation. That's why you want to protect the core internet itself, as I say, with some of the situations I had before. But there's no easy solution to control the dark one.

(There is some story about Pastal.) John Pastal? Yeah, he worked for me here. He did a very interesting dissertation. He left here and went to work at ISI information sciences. And we ended the domain name system at one time. He import more compatriots, put together DNS. He looked like a hippy, but he wasn't. Wow, he was a nerd kind of guy. Very serious, very smart, very honest. And he didn't mind saying someone was doing something stupid. He was very open about that. And very, very, unbiased about the race or something. It was a pleasure to work with him. And he, Vint Cerf, and Steve Crocker were key members of my software code. They would sit over there on that side of the desk where you are and squeeze money out of me to travel to meetings where they had a meet-up the rest of their colleagues. And it was a good use of the money. But I remember we'd have that discussion all the time. You know, those guys started the network working for, as I told you that Doppler was very good at giving money to principal investigators PIs gave it to the graduate students. What do they do? They gave that kind of uh, flexibility to their other graduate student classmates around the country. So they form their own group independent of us, never working group. And they did a lot of great work, including the hostel's protocol, without a lot of supervision, we wanted them to do it on their own.

So, uh, the openness and the ability to create those kinds of groups was extremely valuable. It’s something maybe China needs to learn to not only allow collaboration but gives freedom, flexibility. Failure is okay. You have to understand that. In fact, if you're not failing, you don’t know the state. You're not failing, you're not at the edge enough. You are not trying hard enough.

BZ: I noticed you have a watch like a very unusual.

LK: Casio? About forty years old. It’s one of the best watches Casio ever made. It’s a full scientific calculator. You can do x to the y any number, any power, trig logarithm.

BZ: And can I take a picture of us? Well, we'll have a very quick picture with you. I'll help you sit down there. Thank you so much for spending so much time with us.

LK: My pleasure. I'll send you a copy of that paper. You've seen my website. Have you? All my papers are there. And I’ll send this particular one.

I don't eat lunch, really. You know, eat lunch, except when I'm traveling. It takes so much time, I go swimming or do some exercise. I hope that I can run my daughter. She'll run sixty miles out, sixty, seventy miles. She's a trail runner as opposed to road runner. She's amazing.

某人：最后一个问题，你担心互联网的黑暗面吗？目前，一些大众媒体的注意力在暗网上，有信息表明，我们对暗网的了解只是冰山一角。制造暗网的人越来越充满恶意，越来越邪恶。我们能做些什么来终止暗流，终止地下世界的存在呢？

LK：这是一个难题，因为互联网比暗网更为复杂。它有一个所谓的连通域，进入到中心网络，中心内的任何东西都可以到达中心内的其他任何东西。在连通域这边的东西，它们能进来，但无法回到这边。这边的东西可以离开中心网络，抵达外部。我们无法回到这儿。有一些像这样的维度，其中一个就是暗网，你可以从全球互联网上获取它；它是有保护的，很难再回来。关键是，如果你不知道自己在做什么，就不会想要进入它。很多事发生在那儿，很多匿名者会去那儿，朝着它的范例去。洋葱路由中，匿名是最重要的。你无法阻止人们有效地制造邪恶。暗网是成型的，有专家在使用它，黑客们非常……他们总是比你领先一步，你只知道他们做了些事，却不知道他们是何时做的，所以这是很困难的情形。这就是为什么你想要保护核心网络本身，和我之前遇到的一些情况一样。但是要控制暗网很难。

（有个故事是关于帕斯塔尔的。）约翰·帕斯塔尔？他曾经在这儿，为我工作过。他写过一篇很有趣的论文，后来离开了这儿，去了 ISI 信息科学公司工作。我们一度结束了域名系统。他引入了更多的同胞，建立起 DNS。他看上去像个嬉皮士，其实不是。他是个书呆子，非常严肃，非常聪明，非常诚实。他不介意说某人在做傻事，对此很坦率，不带任何偏见。和他一起工作很愉快。他和文顿·瑟夫、史蒂夫·克罗克是我软件代码组的关键成员。他们会坐在你所在的桌子那边，从我这儿敲诈些钱去参加会议，在会议上和其他同事见面。这钱用得很好。但我记得我们总在讨论经费问题。这些人开始为网络工作，就像我告诉你的，多普勒很擅长给主要调查人员分钱，PI 则擅长给研究生分钱。他们干什么？他们给全国其他的研究生同学提供了这种灵活性，所以他们成立了独立于我们的团体，不是工作组。他们做了很多伟大的工作，包括没有监督而制定协议。我们希望他们能独立来做。

所以，开放和创造这些团体的能力是特别珍贵的，也许中国需要学的，不仅是允许合作，还有给予自由和灵活性。失败无所谓，你得明白这一点。事实上，如果你不曾失败，就不会知道情况是怎样的。你没有失败过，就不具备足够的优势；你不够努力。

钟布：我注意到你有一块很特别的手表。

LK：卡西欧？这表有 40 年了，它是卡西欧制造的最好的手表之一，是一台完整的科学计算器。你可以做 x 到 y 的任何数字，任何力量，三重对数。

钟布：我们一起照张相吧？很快。非常感谢你能抽出这么多时间接待我们。

LK：这是我的荣幸。我会把那篇论文的副本寄给你。你看过我的网站，是吗？我所有的论文都在那儿，这一篇我会发给你。

我真不吃午饭，只在旅行时才吃。午饭占的时间太长，我一般用这时间去游游泳或是做些运动。我女儿也跑步，她能跑六十多七十英里，她是跑越野的，不跑公路。她非常了不起。